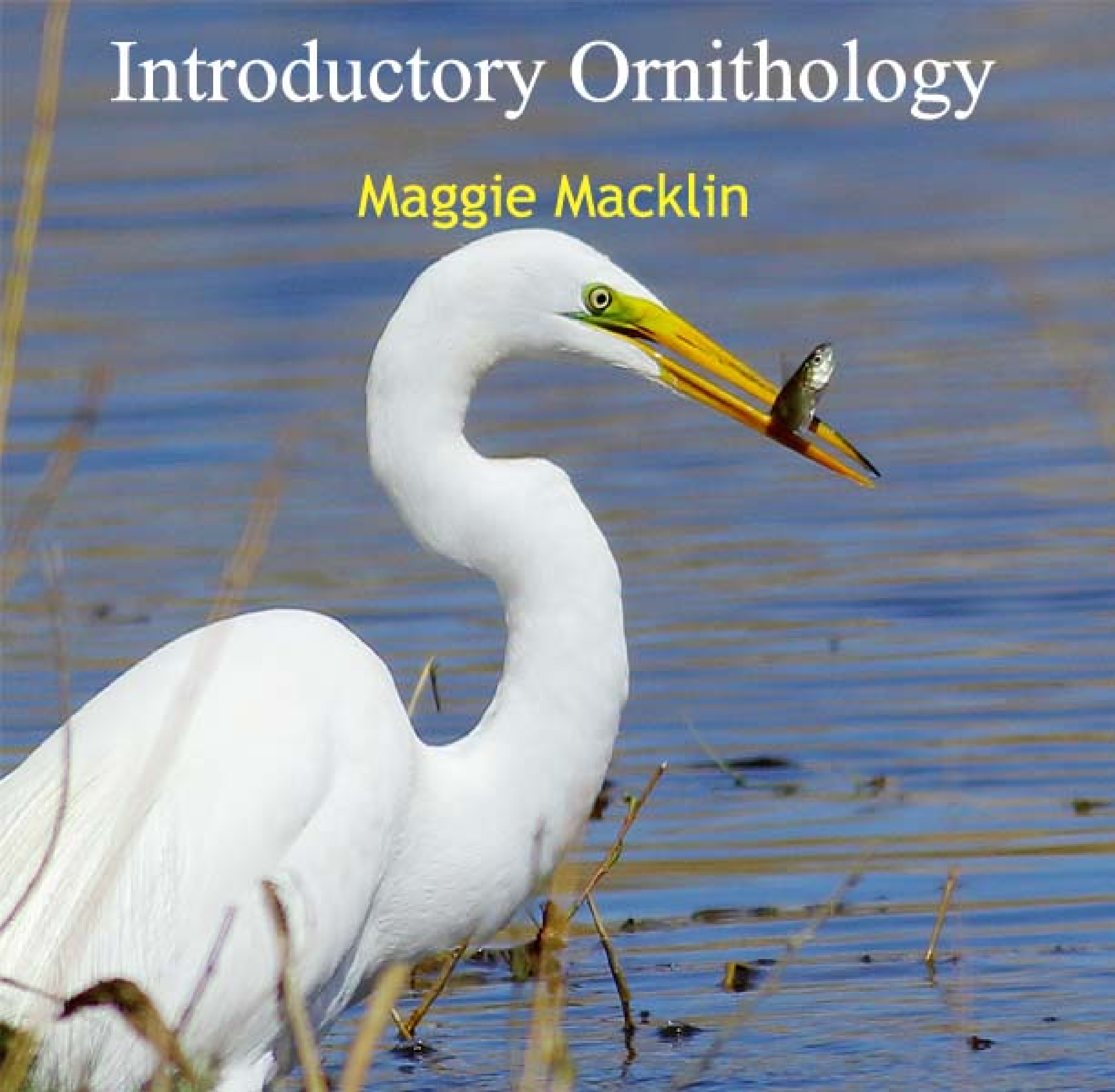
Introductory Ornithology

Maggie Macklin



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Ornithology

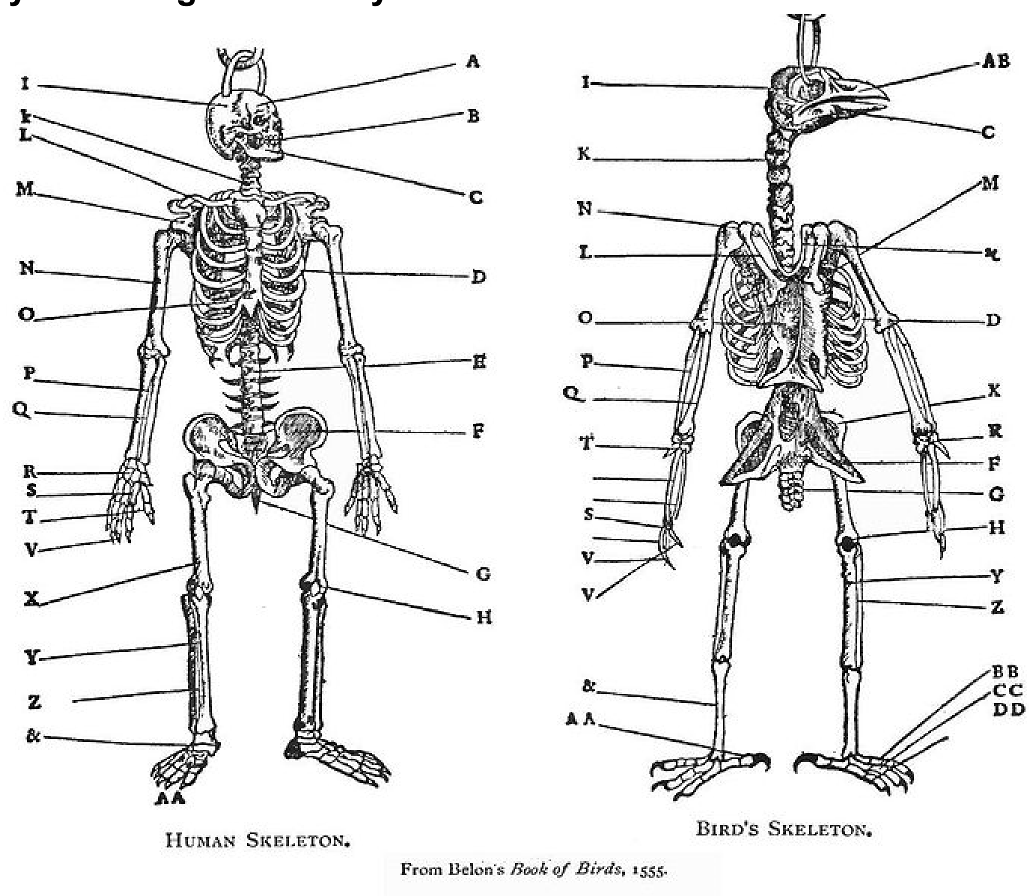
Ornithology (from Greek: ὄρνις, ὄρνιθος, *ornis*, *ornithos*, "bird"; and λόγος, *logos*, "knowledge") is a branch of zoology that concerns the study of birds. Several aspects of ornithology differ from related disciplines, due partly to the high visibility and the aesthetic appeal of birds. Most marked among these is the extent of studies undertaken by amateurs working within the parameters of strict scientific methodology.

The science of ornithology has a long history and studies on birds have helped develop several key concepts in evolution, behaviour and ecology such as the definition of species, the process of speciation, instinct, learning, ecological niches, guilds, island biogeography, phylogeography and conservation. While early ornithology was principally concerned with descriptions and distributions of species, ornithologists today seek answers to very specific questions, often using birds as models to test hypotheses or predictions based on theories. Most modern biological theories apply across taxonomic groups and the number of professional scientists who identify themselves as "ornithologists" has therefore declined. A wide range of tools and techniques are used in ornithology and innovations are constantly made.

History

The history of ornithology largely reflects the trends in the history of biology. Trends include the move from mere descriptions to the identification of patterns and then towards elucidating the processes that produce the patterns.

Early knowledge and study



Belon's comparison of birds and humans in his *Book of Birds*, 1555

Humans must have observed birds from the earliest times, and stone age drawings are among the oldest indications of an interest in birds. Birds were perhaps important as a food source, and bones of as many as 80 species have been found in excavations of early Stone Age settlements.

Cultures around the world have rich vocabularies related to birds. Traditional bird names are often based on detailed knowledge of the behaviour, with many names being onomatopoeic, many still in use. Traditional knowledge may also involve the use of birds in folk medicine and knowledge of these practices are passed on through oral traditions. Hunting of wild birds as well as their domestication would have required considerable knowledge of their habits. Poultry farming and falconry were practised from early times in many parts of the world. Artificial incubation of poultry was practised in China around 246 BC and around at least 400 BC in Egypt. The Egyptians also made use of birds in their hieroglyphic scripts, many of which, though stylized, are still identifiable to species.

Cover of Ulisse Aldrovandi's Ornithology, 1599

Early written records provide valuable information on the past distributions of species. For instance Xenophon records the abundance of the Ostrich in Assyria (Anabasis, i. 5); this subspecies from Asia minor is extinct and all extant Ostrich races are today restricted to Africa. Other old writings such as the *Vedas* (1500-800 BC) demonstrate the careful observation of avian life histories and includes the earliest reference to the habit of brood parasitism by the Asian Koel (*Eudynamys scolopacea*). Like writing, the early art of China, Japan, Persia and India also demonstrate knowledge, with examples of scientifically accurate bird illustrations.

Aristotle in 350 BC in his *Historia Animalium* noted the habit of bird migration, moulting, egg laying and life spans. He however introduced and propagated several myths, such as the idea that swallows hibernated in winter although he noted that cranes migrated from the steppes of Scythia to the marshes at the headwaters of the Nile. The idea of swallow hibernation became so well established that, even as late as in 1878, Elliott Coues could list as many as 182 contemporary publications dealing with the hibernation of swallows and little published evidence to contradict the theory. Similar misconceptions existed regarding the breeding of Barnacle geese. Their nests had not been seen and it was believed that they grew by transformations of goose barnacles, an idea that became prevalent from around the 11th century and noted by Bishop Giraldus Cambrensis (Gerald of Wales) in *Topographia Hiberniae* (1187).

The origins of falconry have been traced to Mesopotamia and the earliest record comes from the reign of Sargon II (722–705 BC). Falconry made its entry to Europe only after AD 400, brought in from the East after invasions by the Huns and Allans. Frederick II of Hohenstaufen (1194–1250) learnt about Arabian falconry during wars in the region and obtained an Arabic treatise on falconry by Moamyn. He had this work translated into Latin and also conducted experiments on birds in his menagerie. By sealing the eyes of vultures and placing food nearby, he concluded that they found food by sight, and not by smell. He also developed methods to keep and train falcons. The studies that he undertook over nearly 30 years, were published in 1240 as De Arte Venandi cum Avibus (The Art of Hunting with Birds), considered one of the earliest studies on bird behaviour.

Several early German and French scholars compiled old works and conducted new research on birds. These included Guillaume Rondelet who described his observations in the Mediterranean and Pierre Belon who described the fish and birds that he had seen in France and the Levant. Belon's Book of Birds (1555) is a folio volume with descriptions of some two hundred species. His comparison of the skeleton of humans and birds is considered as a landmark in comparative anatomy. Volcher Coiter (1534–1576), a Dutch anatomist made detailed studies of the internal structures of birds and produced a classification of birds, *De Diferentiis Avium* (around 1572), that was based on structure and habits. Konrad Gesner wrote the *Vogelbuch* and *Icones avium omnium* around 1557. Like Gesner, Ulisse Aldrovandi, an encyclopedic naturalist began a 14-volume natural history with three volumes on birds, entitled *ornithologiae hoc est de avibus historiae libri XII* which was published from 1599 to 1603. Aldrovandi showed great interest in plants and animals and his work included 3000 drawings of fruits, flowers, plants and animals, published in 363 volumes. His *Ornithology* alone covers 2000 pages and included such aspects as the chicken and poultry techniques.William Turner's *Historia Avium* ("History of Birds"), published at Cologne in 1544, was an early ornithological work from England. He noted the commonness of kite in English cities where they snatched food out of the hands of children. He included folk beliefs such as those of anglers. Anglers believed that the Osprey emptied their fishponds and would kill them, mixing the flesh of the Osprey into their fish bait. Turner's work reflected the violent times that he lived in and stands in contrast to later works such as Gilbert White's *The Natural History and Antiquities of Selborne* that were written in a tranquil era.

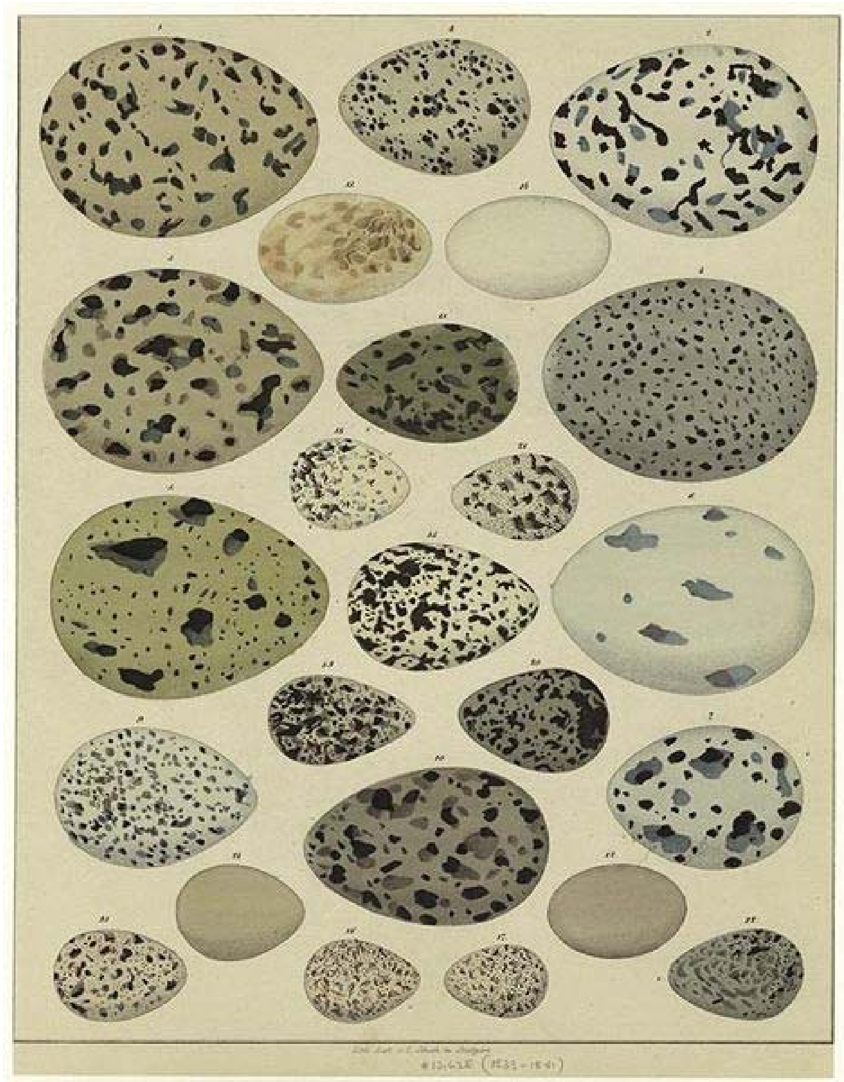
Antonio Valli da Todi who wrote on aviculture in 1601 knew the connections between territory and song

In the 17th century Francis Willughby (1635–1672) and John Ray (1627–1705) came up with the first major system of bird classification that was based on function and morphology rather than on form or behaviour. Willughby's *Ornithologiae libri tres* (1676) completed by John Ray is sometimes considered to mark the beginning of scientific ornithology. Ray also worked on *Ornithologia* which was published posthumously in 1713 as *Synopsis methodica avium et piscium*. The earliest list of British birds, *Pinax Rerum Naturalium Britannicarum* was written by Christopher Merrett in 1667, however it was not considered of value by many including John Ray.

An Experiment on a Bird in the Air Pump, 1768

Towards the late 18th century, Mathurin Jacques Brisson (1723–1806) and Comte de Buffon (1707–1788) began new works on birds. Brisson produced a six-volume work *Ornithologie* in 1760 and Buffon's included nine volumes (volumes 16-24) on birds *Histoire naturelle des oiseaux* (1770–1785) in his work on science *Histoire naturelle générale et particulière* (1749–1804). Coenraad Jacob Temminck (1778–1858) sponsored François Le Vaillant [1753-1824] to collect bird specimens in Africa and this resulted in Le Vaillant's six-volume *Histoire naturelle des oiseaux d'Afrique* (1796–1808). Louis Jean Pierre Vieillot (1748–1831) spent ten years studying North American birds and wrote the *Histoire naturelle des oiseaux de l'Amerique septentrionale* (1807-1808?). Vieillot pioneered in the use of life-histories and habits in classification.

Scientific studies



Early bird study focused on collectibles such as eggs and nests

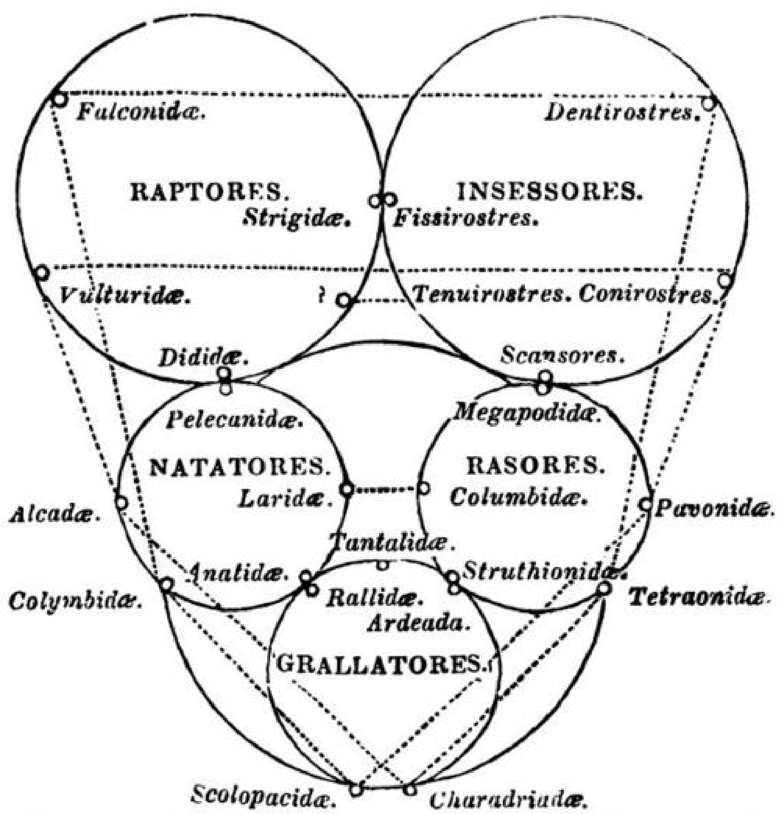
It was not until the Victorian era—with the emergence of the gun, the concept of natural history, and the collection of natural objects such as bird eggs and skins—that ornithology emerged as a specialized science. This specialization led to the formation in Britain of the British Ornithologists' Union in 1858. In 1859 the members founded its journal *The Ibis*. The sudden spurt in ornithology was also due in part to colonialization. A hundred years later, in 1959, R. E. Moreau noted that ornithology in this period was preoccupied with the geographical distributions of various species of birds.

No doubt the preoccupation with widely extended geographical ornithology, was fostered by the immensity of the areas over which British rule or influence stretched during the 19th century and for some time afterwards.
—Moreau

The bird collectors of the Victorian era observed the variations in bird forms and habits across geographic regions, noting local specialization and variation in widespread species. The collections of museums and private collectors grew with contributions from various parts of the world. The naming of species with binomials and the organization of birds into groups based on their similarities became the main work of museum specialists. The variations in widespread birds across geographical region caused the introduction of trinomial names.

The search for patterns in the variations of birds was attempted by many. Early ornithologists like William Swainson followed the Quinarian system and this was replaced by more complex "maps" of affinities in works by Hugh Edwin Strickland and Alfred Russell Wallace.

The Galapagos finches were especially influential in the development of Charles Darwin's theory of evolution. His contemporary Alfred Russel Wallace also noted these variations and the geographical separations between different forms leading to the study of biogeography. Wallace was influenced by the work of Philip Lutley Sclater on the distribution patterns of birds.



Affinities and analogies among the groups according to Swainson. The circles touch with groups on them having "affinities", but the lines connect groups that showed "analogies".

Quinarian system of bird classification by Swainson

For Darwin, the problem was how species arose from a common ancestor, but he did not attempt to find rules for delineation of species. The species problem was tackled by the ornithologist Ernst Mayr. Mayr was able to demonstrate that geographical isolation and the accumulation of genetic differences led to the splitting of species.

Early ornithologists were preoccupied with matters of species identification. Only systematics counted as true science and field studies were considered inferior through much of the 19th century. In 1901 Robert Ridgway wrote in the introduction to *The Birds of North and Middle America* that:

There are two essentially different kinds of ornithology: systematic or scientific, and popular. The former deals with the structure and classification of birds, their synonymies and technical descriptions. The latter treats of their habits, songs, nesting, and other facts pertaining to their life histories.

This early idea that the study of *living birds* was merely recreation held sway until ecological theories became the predominant focus of ornithological studies. The study of birds in their habitats was particularly advanced in Germany with bird ringing stations established as early as 1903. By the 1920s the *Journal für Ornithologie* included many papers on the behaviour, ecology, anatomy and physiology, many written by Erwin Stresemann. Stresemann changed the editorial policy of the journal, leading both to a unification of field and laboratory studies and a shift of research from museums to universities. Ornithology in the United States continued to be dominated by museum studies of morphological variations, species identities and geographic distributions, until it was influenced by Stresemann's student Ernst Mayr. In Britain, some of the earliest ornithological works that used the word ecology appeared in 1915. *The Ibis* however resisted the introduction of these new methods of study and it was not until 1943 that any paper on ecology appeared. The work of David Lack on population ecology was pioneering. Newer quantitative approaches were introduced for the study of ecology and behaviour and this was not readily accepted. For instance, Claud Ticehurst wrote:

Sometimes it seems that elaborate plans and statistics are made to prove what is commonplace knowledge to the mere collector, such as that hunting parties often travel more or less in circles.
—Ticehurst

David Lack's studies on population ecology sought to find the processes involved in the regulation of population based on the evolution of optimal clutch sizes. He concluded that population was regulated primarily by density-dependent controls, and also suggested that natural selection produces life-history traits that maximize the fitness of individuals. Others like Wynne-Edwards interpreted population regulation as a mechanism that aided the "species" rather than individuals. This led to widespread and sometimes bitter debate on what constituted the "unit of selection". Lack also pioneered the use of many new tools for ornithological research, including the idea of using radar to study bird migration.

Birds were also widely used in studies of the niche hypothesis and Georgii Gause's competitive exclusion principle. Work on resource partitioning and the structuring of bird communities through competition were made by Robert MacArthur. Patterns of biodiversity also became a topic of interest. Work on the relationship of the number of species to area and its application in the study of island biogeography was pioneered by E. O. Wilson and Robert MacArthur. These studies led to the development of the discipline of landscape ecology.

A mounted specimen of a Red-footed Falcon

John Hurrell Crook studied the behaviour of weaverbirds and demonstrated the links between ecological conditions, behaviour and social systems. Principles from economics were introduced to the study of biology by Jerram L. Brown. This led to the study of behaviour using cost-benefit analyses. The rising interest in sociobiology also led to a spurt of bird studies in this area.

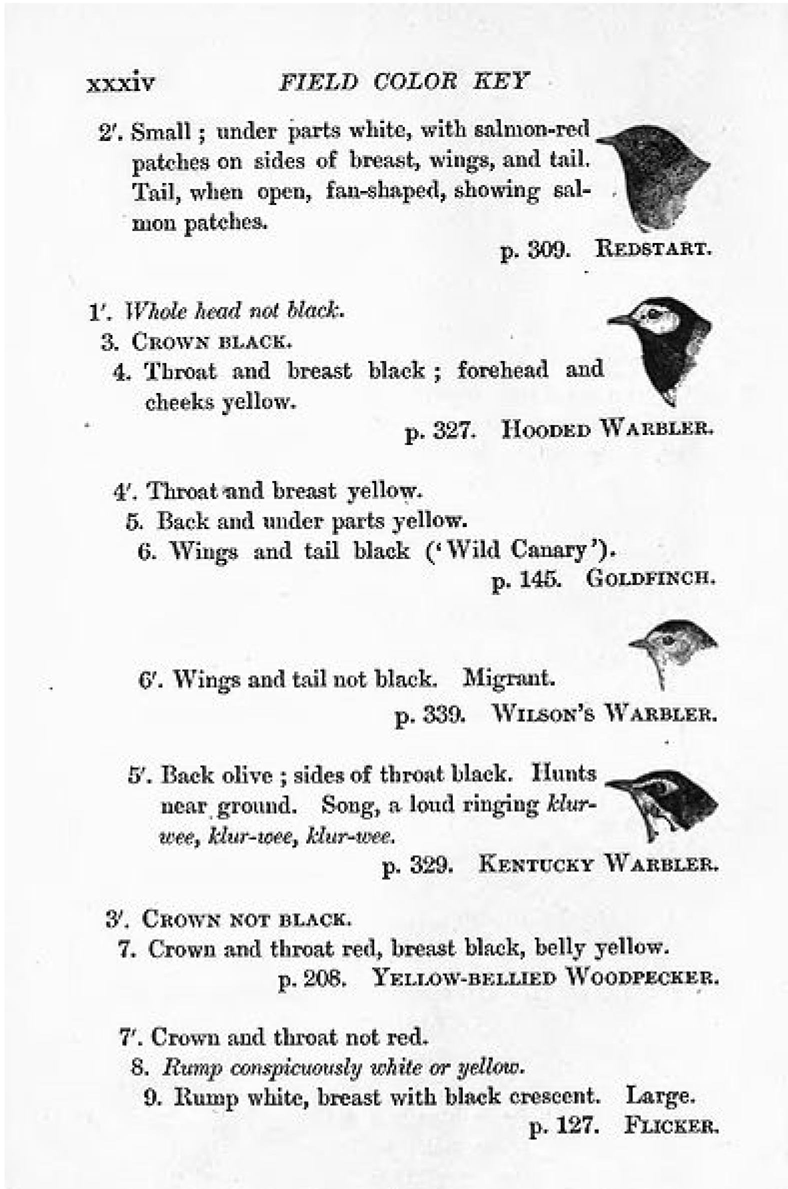
The study of imprinting behaviour in ducks and geese by Konrad Lorenz and the studies of instinct in Herring Gulls by Nicolaas Tinbergen, led to the establishment of the field of ethology. The study of learning became an area of interest and the study of bird song has been a model for studies in neuro-ethology. The role of hormones and physiology in the control of behaviour has also been aided by bird models. These have helped in the study of circadian and seasonal cycles. Studies on migration have attempted to answer questions on the evolution of migration, orientation and navigation.

The growth of genetics and the rise of molecular biology led to the application of the gene-centered view of evolution to explain avian phenomena. Studies on kinship and altruism, such as helpers, became of particular interest. The idea of inclusive fitness was used to interpret observations on behaviour and life-history and birds were widely used models for testing hypotheses based on theories postulated by W. D. Hamilton and others.

The new tools of molecular-biology changed the study of bird systematics. Systematics changed from being based on phenotype to the underlying genotype. The use of techniques such as DNA-DNA hybridization to study evolutionary relationships was pioneered by Charles Sibley and Jon Edward Ahlquist resulting in what is called the Sibley-Ahlquist taxonomy. These early techniques have been replaced by newer ones based on mitochondrial DNA sequences and molecular phylogenetics approaches that make use of computational procedures for sequence alignment, construction of phylogenetic trees and calibration of molecular clocks to infer evolutionary relationships. Molecular techniques are also widely used in studies of avian population biology and ecology.

Rise to popularity

The use of field glasses or telescopes for bird observation began in the 1820s and 1830s with pioneers like J. Dovaston (who also pioneered in the use of bird-feeders), but it was not until the 1880s that instruction manuals began to insist on the use of optical aids such as "a first-class telescope" or "field glass."



xxxiv *FIELD COLOR KEY*

2′. Small ; under parts white, with salmon-red patches on sides of breast, wings, and tail. Tail, when open, fan-shaped, showing salmon patches.
p. 309. REDSTART.

1′. *Whole head not black.*
3. CROWN BLACK.
4. Throat and breast black ; forehead and cheeks yellow.
p. 327. HOODED WARBLER.

4′. Throat and breast yellow.
5. Back and under parts yellow.
6. Wings and tail black ('Wild Canary').
p. 145. GOLDFINCH.

6′. Wings and tail not black. Migrant.
p. 339. WILSON'S WARBLER.

5′. Back olive ; sides of throat black. Hunts near ground. Song, a loud ringing *klur-wee, klur-wee, klur-wee.*
p. 329. KENTUCKY WARBLER.

3′. CROWN NOT BLACK.
7. Crown and throat red, breast black, belly yellow.
p. 208. YELLOW-BELLIED WOODPECKER.

7′. Crown and throat not red.
8. *Rump conspicuously white or yellow.*
9. Rump white, breast with black crescent. Large.
p. 127. FLICKER.

Page from an early field guide by Florence Augusta Merriam Bailey

The rise of field guides for the identification of birds was another major innovation. The early guides were large and cumbersome and were mainly focused on identifying specimens in the hand. The earliest of the new generation of field guides was prepared by Florence Merriam, sister of Clinton Hart Merriam, the mammalogist. This was published in 1887 in a series *Hints to Audubon Workers:Fifty Birds and How to Know Them* in Grinnell's *Audubon Magazine*. These were followed by new field guides including classics by Roger Tory Peterson.

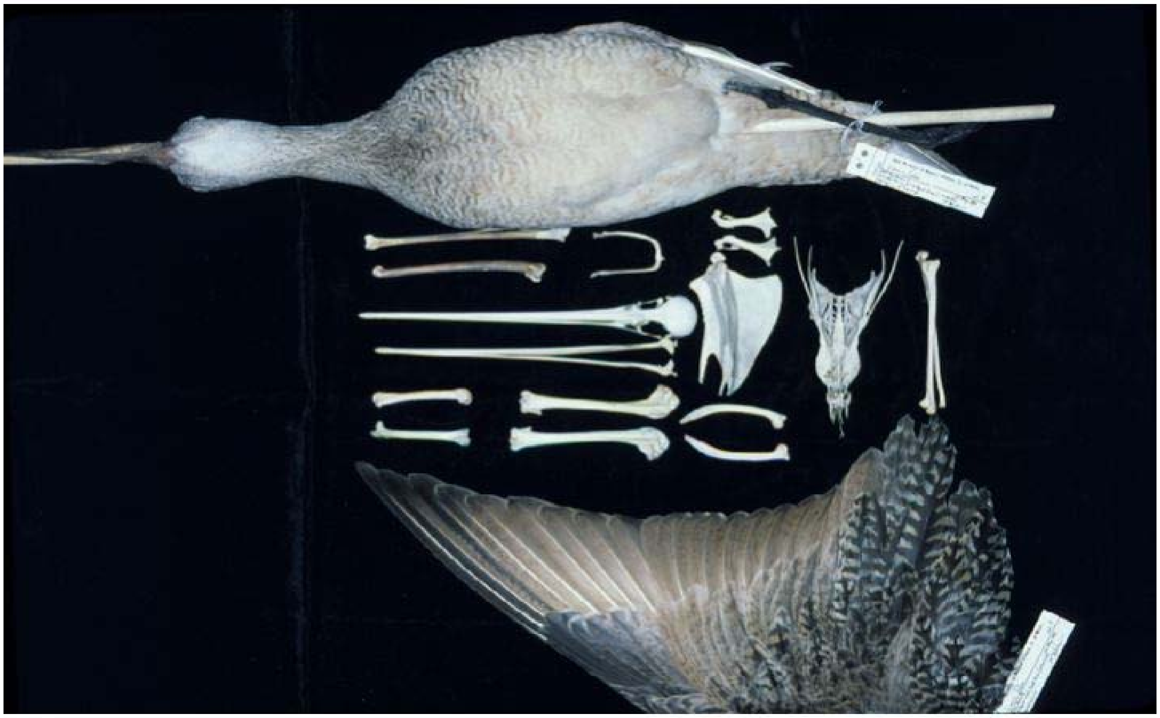
The interest in birdwatching grew in popularity in many parts of the world and it was realized that there was a possibility for amateurs to contribute to the professional biology. As early as 1916, Julian Huxley wrote a two part article in the *Auk*, noting the tensions between amateurs and professionals and suggesting the possibility that the "vast army of bird-lovers and bird-watchers could begin providing the data scientists needed to address the fundamental problems of biology."

Organizations were started in many countries and these grew rapidly in membership, most notable among them being the Royal Society for the Protection of Birds (RSPB) in Britain and the Audubon Society in the US. The Audubon Society started in 1885. Both these organizations were started with the primary objective of conservation. The RSPB, born in 1889, grew from a small group of women in Croydon who met regularly and called themselves the *Fur, Fin and Feather Folk* and who took a pledge "to refrain from wearing the feathers of any birds not killed for the purpose of food, the Ostrich only exempted." The organization did not allow men as members initially, avenging a policy of the British Ornithologists' Union to keep out women. Unlike the RSPB, which was primarily conservation oriented, the British Trust for Ornithology (BTO) was started in 1933 with the aim of advancing ornithological research. Members were often involved in collaborative ornithological projects. These projects have resulted in atlases which detail the distribution of bird species across Britain. In the United States, the Breeding Bird Surveys, conducted by the US Geological Survey have also produced atlases with information on breeding densities and changes in the density and distribution over time. Other volunteer collaborative ornithology projects were subsequently established in other parts of the world.

Techniques

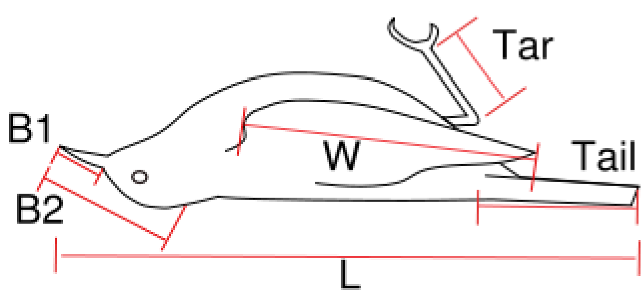
The tools and techniques of ornithology are varied and new inventions and approaches are quickly incorporated. The techniques may be broadly dealt under the categories of those that are applicable to specimens and those that are used in the field, however the classification is rough and many analysis techniques are usable both in the laboratory and field or may require a combination of field and laboratory techniques.

Collections



Bird preservation techniques

The earliest approaches to modern bird study involved the collection of eggs, a practice known as oology. While collecting became a pastime for many amateurs, the labels associated with these early egg collections made them unreliable for the serious study of bird breeding. In order to preserve eggs, a tiny hole was pierced and the contents extracted. This technique became standard with the invention of the blow drill around 1830. Egg collection is no longer popular; however historic museum collections have been of value in determining the effects of pesticides such as DDT on physiology. Museum bird collections continue to act as a resource for taxonomic studies.



Morphometric measurements of birds are important in systematics

The use of bird skins to document species has been a standard part of systematic ornithology. Bird skins are prepared by retaining the key bones of the wings, leg and skull along with the skin and feathers. In the past, they were treated with arsenic to prevent fungal and insect (mostly dermestid) attack. Arsenic, being toxic, was replaced by borax. Sportsmen became familiar with these skinning techniques and started sending in their skins to museums, some of them from distant locations. This led to the formation of huge collections of bird skins in museums in Europe and North America. Many private collections were also formed. These became references for comparison of species and the ornithologists at these museums were able to compare species from different locations, often places that they themselves never visited. Morphometrics of these skins, particularly the lengths of the tarsus, bill, tail and wing became important in the descriptions of bird species. These skin collections have been utilized in more recent times for studies on molecular phylogenetics by the extraction of ancient DNA. The importance of type specimens in the description of species make skin collections a vital resource for systematic ornithology. However, with the rise of molecular techniques, it has now become possible to establish the taxonomic status of new discoveries, such as the Bulo Burti Boubou *Laniarius liberatus* (no longer a valid species) and the Bugun Liocichla *Liocichla bugunorum*, using blood, DNA and feather samples as the holotype material.

Other methods of preservation include the storage of specimens in spirit. Such wet-specimens have special value in physiological and anatomical study, apart from providing better quality of DNA for molecular studies. Freeze drying of specimens is another technique that has the advantage of preserving stomach contents and anatomy, although it tends to shrink making it less reliable for morphometrics.

In the field

The study of birds in the field was helped enormously by improvements in optics. Photography made it possible to document birds in the field with great accuracy. High power spotting scopes today allow observers to detect minute morphological differences that were earlier possible only by examination of the specimen *in the hand*.

A bird caught in a mist net

The capture and marking of birds enables detailed studies of life-history. Techniques for capturing birds are varied and include the use of bird liming for perching birds, mist nets for woodland birds, cannon netting for open area flocking birds, the bal-chatri trap for raptors, decoys and funnel traps for water birds.

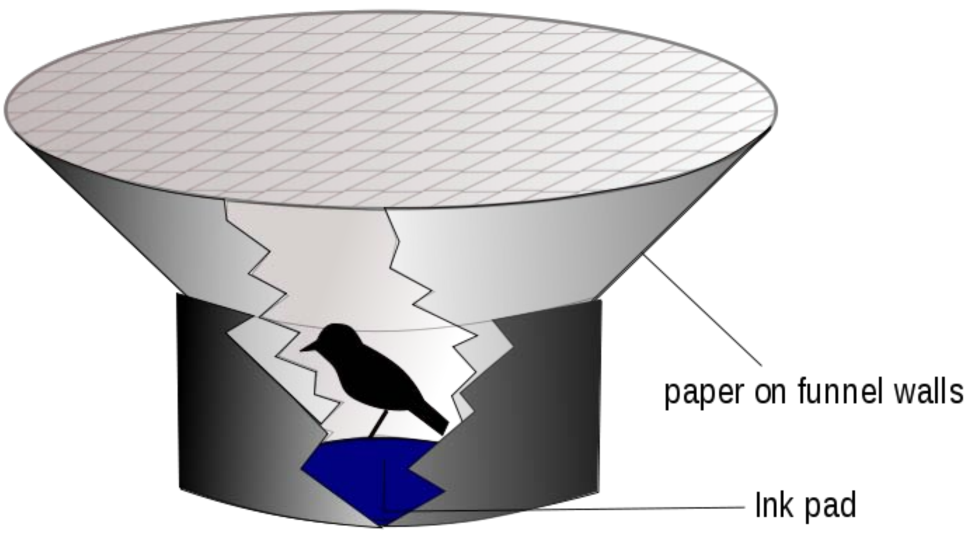
A Californian Condor marked with wing tags

The bird in the hand may be examined and measurements can be made including standard lengths and weight. Feather moult and skull ossification provide indications of age and health. Sex can be determined by examination of anatomy in some sexually non-dimorphic species. Blood samples may be drawn to determine hormonal conditions in studies of physiology, identify DNA markers for studying genetics and kinship in studies of breeding biology and phylogeography. Blood may also be used to pathogens and arthropod borne viruses. Ectoparasites may be collected for studies of coevolution and zoonoses. In many of cryptic species, measurements (such as the relative lengths of wing feathers in warblers) are vital in establishing identity.

Captured birds are often marked for future recognition. Rings or bands provide long-lasting identification but require capture for the information on them to be read. Field identifiable marks such as coloured bands, wing tags or dyes enable short-term studies where individual identification is required. Mark and recapture techniques make demographic studies possible. Ringing has traditionally been used in the study of migration. In recent times satellite transmitters provide the ability to track migrating birds in near real-time.

Techniques for estimating population density include point counts, transects and territory mapping. Observations are made in the field using carefully designed protocols and the data may be analysed to estimate bird diversity, relative abundance or absolute population densities. These methods may be used repeatedly over large time spans to monitor changes in the environment. Camera traps have been found to be a useful tool for the detection and documentation of elusive species, nest predators and in the quantitative analysis of frugivory, seed dispersal and behaviour.

In the laboratory



An Emlen funnel is used to study the orientation behaviour in migratory birds

Many aspects of bird biology are difficult to study in the field. These include the study of behavioural and physiological changes that require a long duration of access to the bird. Non-destructive samples of blood or feathers taken during field studies may be studied in the laboratory. For instance, the variation in the ratios of stable hydrogen isotopes across latitudes makes it possible to roughly establish the origins of migrant birds using mass spectrometric analysis of feather samples. These techniques can be used in combination with other techniques such as ringing.

The first attenuated vaccine developed by Louis Pasteur was for fowl cholera and was tested on poultry in 1878. Poultry continues to be used as a model for many studies in non-mammalian immunology.

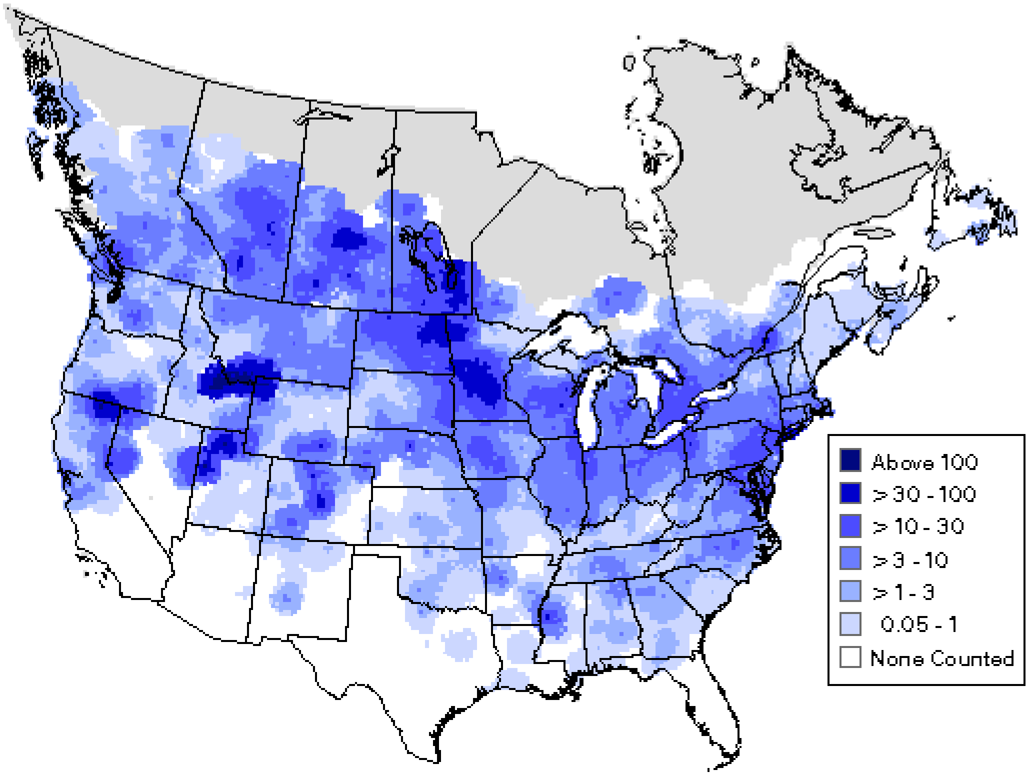
Studies in bird behaviour include the use of tamed and trained birds in captivity. Studies on bird intelligence and song learning have been largely laboratory based. Field researchers may make use of a wide range of techniques such as the use of dummy owls to elicit mobbing behaviour, dummy males or the use of call playback to elicit territorial behaviour and thereby to establish the boundaries of bird territories.

Studies of bird migration including aspects of navigation, orientation and physiology are often studied using captive birds in special cages that record their activities. The Emlen funnel for instance makes use of a cage with an inkpad at the centre and a conical floor where the ink marks can be counted to identify the direction in which the bird attempts to fly. The funnel can have a transparent top and visible cues such as the direction of sunlight may be controlled using mirrors or the positions of the stars simulated in a planetarium.

The entire genome of the domestic fowl *Gallus gallus* was sequenced in 2004 and was followed in 2008 by the genome of the Zebra Finch (*Taeniopygia guttata*). Such whole genome sequencing projects allow for studies on evolutionary processes involved in speciation. Associations between the expression of genes and behaviour may be studied using candidate genes. Variations in the exploratory behaviour of Great Tits (*Parus major*) have been found to be linked with a gene orthologous to the human gene *DRD4* (Dopamine receptor D4) which is known to be associated with novelty-seeking behaviour. The role of gene expression in developmental differences and morphological variations have been studied in Darwin's finches. The difference in the expression of *Bmp4* have been shown to be associated with changes in the growth and shape of the beak.

The chicken has long been a model organism for studying vertebrate developmental biology. As the embryo is readily accessible, its development can be easily followed (unlike mice). This also allows the use of electroporation for studying the effect of adding or silencing a gene. Other tools for perturbing their genetic makeup are chicken embryonic stem cells and viral vectors.

Collaborative studies

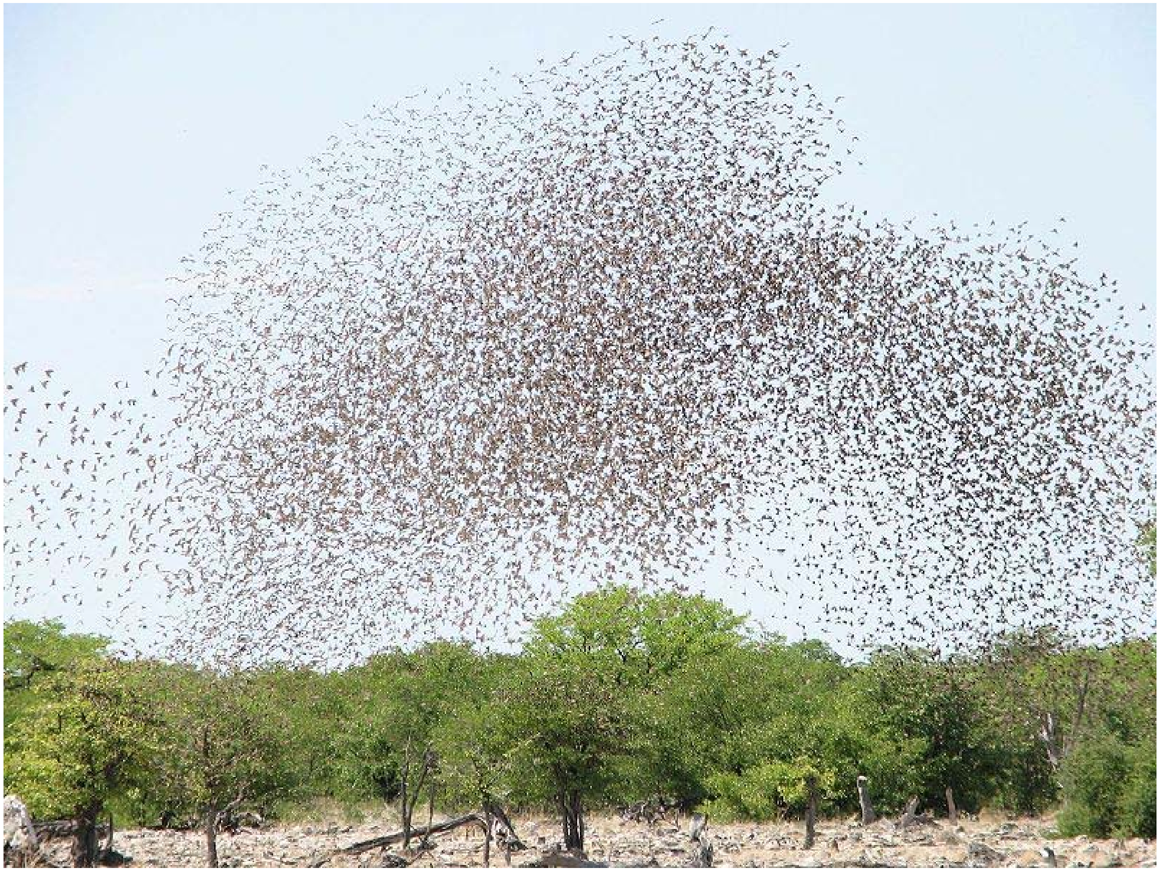


Summer distribution and abundance of Canada Goose using data from the North American Breeding Bird Surveys 1994-2003

With the widespread interest in birds, it has been possible to use a large number of people to work on collaborative ornithological projects that cover large geographic scales. These citizen science projects include nation-wide projects such as the *Christmas Bird Count*, *Backyard Bird Count*, the North American *Breeding Bird Survey*, the Canadian EPOQ or regional projects such as the *Asian Waterfowl Census* and *Spring Alive* in Europe. These projects help to identify distributions of birds, their population densities and changes over time, arrival and departure dates of migration, breeding seasonality and even population genetics. The results of many of these projects are published as bird atlases. Studies of migration using bird ringing or colour marking often involve the cooperation of people and organizations in different countries.

Applications

Wild birds impact many human activities while domesticated birds are important sources of eggs, meat, feathers and other products. Applied and economic ornithology aim to reduce the ill effects of problem birds and enhance gains from beneficial species.



Red-billed Quelea are a major agricultural pest in parts of Africa

The role of some species of birds as pests has been well known, particularly in agriculture. Granivorous birds such as the queleas in Africa are among the most numerous birds in the world and foraging flocks can cause devastation. Many insectivorous birds are also noted as beneficial in agriculture. Many early studies on the benefits or damages caused by birds in fields were made by analysis of stomach contents and observation of feeding behaviour. Modern studies aimed to manage birds in agriculture make use of a wide range of principles from ecology. Intensive aquaculture has brought humans in conflict with fish-eating birds such as cormorants.

Large flocks of pigeons and starlings in cities are often considered as a nuisance and techniques to reduce their populations or their impacts are constantly innovated. Birds are also of medical importance and their role as carriers of human diseases such as Japanese Encephalitis, West Nile Virus and H5N1 have been widely recognised. Bird strikes and the damage they cause in aviation are of particularly great importance, due to the fatal consequences and the level of economic losses caused. It has been estimated that the airline industry incurs worldwide damages of US $ 1.2 billion each year.

Many species of birds have been driven to extinction by human activities. Being conspicuous elements of the ecosystem, they have been considered as indicators of ecological health. They have also helped in gathering support for habitat conservation.

Bird conservation requires specialized knowledge in aspects of biology, ecology and may require the use of very location specific approaches. Ornithologists contribute to conservation biology by studying the ecology of birds in the wild and identifying the key threats and ways of enhancing the survival of species. Critically endangered species such as the California Condor have had to be captured and bred in captivity. Such ex-situ conservation measures may be followed by re-introduction of the species into the wild.

Chapter- 2

Origin of Avian Flight

The Berlin *Archaeopteryx*, one of the earliest known birds

Around 350 BCE, Aristotle and other philosophers of the time were attempting to explain the aerodynamics of avian flight. Even after the discovery of the ancestral bird *Archaeopteryx*, over 150 years ago, debates still persist regarding the evolution of flight. Currently there are three leading hypotheses pertaining to avian flight: Pouncing Proavis model, Cursorial model, and Arboreal model. *Archaeopteryx*, being the oldest known ancestor of modern birds, could provide clues to the origin of avian flight.

Flight characteristics

For flight to occur in Aves, four physical forces (thrust and drag, lift and weight) must work together. In order for birds to balance these forces, certain physical characteristics are required. Asymmetrical wings, found on all flying birds with the exception of hummingbirds, help in the production of thrust and lift. Anything that moves produces drag due to friction forces. The aerodynamic body of a bird can reduce drag, but when stopping or slowing down a bird will use its tail and feet to increase drag. Weight is the largest obstacle birds must overcome in order to fly. Flying birds have evolved reduced weight through several characteristics. Pneumatic bone is hollow or filled with air sacs, reducing weight. The loss of teeth, gonadal hypertrophy, and fusion of bones also reduce weight. Teeth have been replaced by a light weight bill made of keratin, and chewing occurs in the bird's gizzard. Other physical characteristics required for flight are a keel for the attachment of flight muscles, an enlarged cerebellum for fine motor coordination, and a furcula, which enhances skeletal bracing for the stresses of flight.

Theories

The CGI television series *Prehistoric Park* described a theory that scales turned into contour feathers for heat insulation, and that later the feathers along the back edges of the arms and legs became bigger and longer for displaying (e.g. *Incisivosaurus*), until they were long enough to be used for gliding (e.g. *Microraptor*).

Pouncing Proavis model

A theory of a pouncing proavis was first proposed by Garner, Taylor, and Thomas in 1999:

We propose that birds evolved from predators that specialized in ambush from elevated sites, using their raptorial hindlimbs in a leaping attack. Drag–based, and later lift-based, mechanisms evolved under selection for improved control of body position and locomotion during the aerial part of the attack. Selection for enhanced lift-based control led to improved lift coefficients, incidentally turning a pounce into a swoop as lift production increased. Selection for greater swooping range would finally lead to the origin of true flight.

The authors believed that this theory had four main virtues:

- It predicts the observed sequence of character acquisition in avian evolution.

- It predicts an *Archaeopteryx*-like animal, with a skeleton more or less identical to terrestrial theropods, with few adaptations to flapping, but very advanced aerodynamic asymmetrical feathers.
- It explains that primitive pouncers (perhaps like *Microraptor*) could coexist with more advanced fliers (like *Confuciusornis* or *Sapeornis*) since they did not compete for flying niches.
- It explains that the evolution of elongated rachis-bearing feathers began with simple forms that produced a benefit by increasing drag. Later, more refined feather shapes could begin to also provide lift.

Cursorial model

A cursorial, or "running" model was originally proposed by Samuel Wendell Williston in 1879. This theory states that "flight evolved in running bipeds through a series of short jumps". As the length of the jumps extended, the wings were used not only for thrust but also for stability, and eventually eliminated the gliding intermediate. However, this theory was modified in the 1970s by John Ostrom to describe the use of wings as an insect-foraging mechanism which then evolved into a wing stroke. Research was conducted by comparing the amount of energy expended by each hunting method with the amount of food gathered. The potential hunting volume doubles by running and jumping. To gather the same volume of food, *Archaeopteryx* would expend less energy by running and jumping than by running alone. Therefore, the cost/benefit ratio would be more favorable for this model. Due to *Archaeopteryx* long and erect leg, supporters of this model say the species was a terrestrial bird. This characteristic allows for more strength and stability in the hindlimbs. Thrust produced by the wings coupled with propulsion in the legs generates the minimum velocity required to achieve flight. Thus, through these mechanisms, *Archaeopteryx* was able to achieve flight from the ground up.

Although the evidence in favor of this model is scientifically plausible, the evidence against it is substantial. For instance, a cursorial flight model would be energetically less favorable when compared to the alternative hypotheses. In order to achieve liftoff, *Archaeopteryx* would have to run faster than modern birds by a factor of three, due to its weight. Furthermore, the mass of *Archaeopteryx* versus the distance needed for minimum velocity to obtain liftoff speed being proportional., therefore, as mass increases, the energy required for takeoff increases exponentially. Other research has shown that the physics involved in cursorial flight would not make this a likely answer to the origin of avian flight. Once flight speed is obtained and *Archaeopteryx* is in the air, drag would cause the velocity to instantaneously decrease. In addition, balance could not be maintained due to this immediate reduction in velocity. Hence, *Archaeopteryx* would have a very short and ineffective flight. In contrast to Ostrom's theory regarding flight as a hunting mechanism, physics again does not support this model. In order to effectively trap insects with the wings, *Archaeopteryx* would require a mechanism such as holes in the wings to reduce air resistance. Without this mechanism, the cost/benefit ratio would not be feasible.

Arboreal model

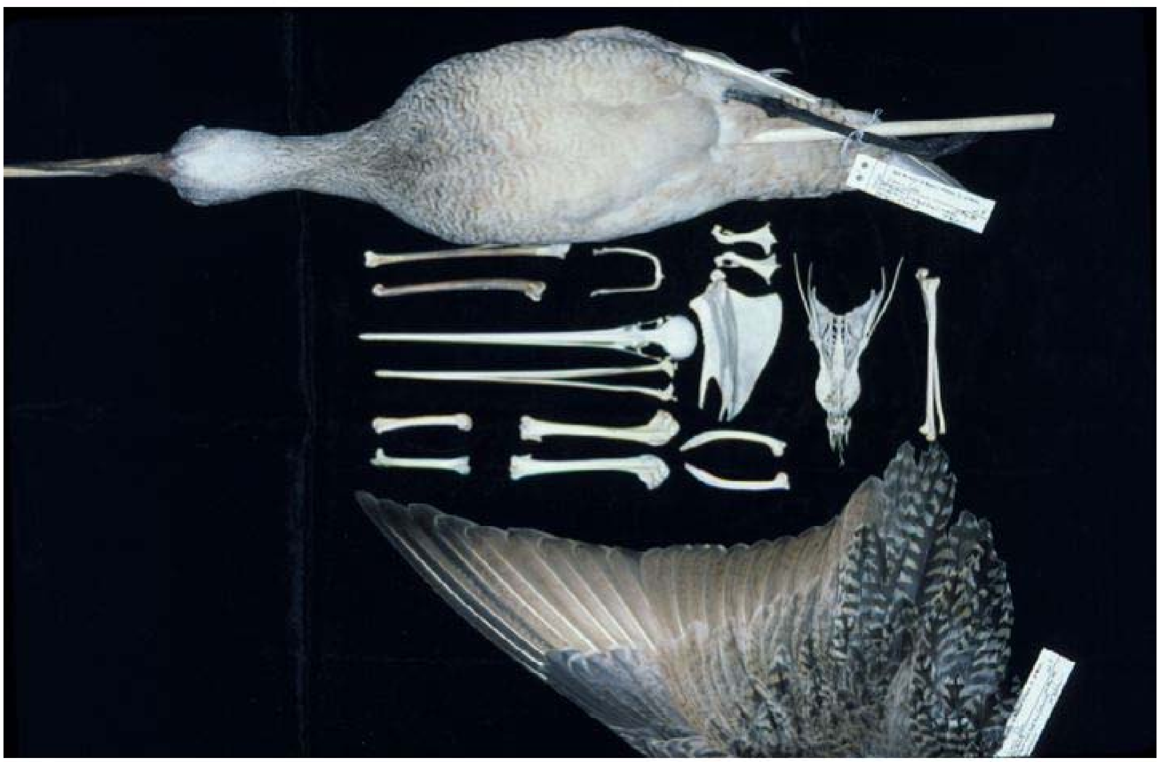
This model was originally proposed in 1880 by Othniel C. Marsh. The theory states *Archaeopteryx* was a reptilian bird that soared from tree to tree. After the leap, *Archaeopteryx* would then use its wings as a balancing mechanism. According to this model, *Archaeopteryx* developed a gliding method to conserve energy. Even though an arboreal *Archaeopteryx* exerts energy climbing the tree, an arboreal *Archaeopteryx* is able to achieve higher velocities and cover greater distances during the gliding phase, which conserves more energy in the long run than a cursorial bipedal runner. Conserving energy during the gliding phase makes this a more energy-efficient model. Therefore, the benefits gained by gliding outweigh the energy used in climbing the tree. A modern behavior model to compare against would be that of the Flying squirrel.

Researchers in support of this model have suggested that *Archaeopteryx* possessed skeletal features similar to those of modern birds. The first such feature to be noted was the supposed similarity between the foot of *Archaeopteryx* and that of modern perching birds. The hallux, or modified of the first digit of the foot, was long thought to have pointed posterior to the remaining digits, as in perching birds. Therefore, researchers once concluded that *Archaeopteryx* used the hallux as a balancing mechanism on tree limbs. However, study of the Thermopolis specimen of *Archeopteryx*, which has the most complete foot of any known, showed that the hallux was not in fact reversed, limiting the creature's ability to perch on branches and implying a terrestrial or trunk-climbing lifestyle.

Another skeletal feature that is similar in *Archaeopteryx* and modern birds is the curvature of the claws. *Archaeopteryx* possessed the same claw curvature of the foot to that of perching birds. However, the claw curvature of the hand in *Archaeopteryx* was similar to that in basal birds. Based upon the comparisons of modern birds to *Archaeopteryx*, perching characteristics were present, signifying an arboreal habitat. The ability for takeoff and flight was originally thought to require a supracoracoideus pulley system (SC). This system consists of a tendon joining the humerus and coracoid process of the scapula allowing rotation of the humerus during the upstroke. However, this system is lacking in *Archaeopteryx*. Based on experiments performed by M. Sy in 1936, it was proven that the SC pulley system was not required for flight from an elevated position but necessary for cursorial takeoff.

Chapter- 3

Bird Collections



Marbled Godwit, *Limosa fedoa*, prepared as a skin (*shmoo*), skeleton, and spread wing

Bird collections are curated repositories of scientific specimens consisting of birds and their parts. They are a research resource for ornithology, the science of birds, and for other scientific disciplines in which information about birds is useful. These collections are archives of avian diversity and serve the diverse needs of scientific researchers, artists, and educators. Collections may include a variety of preparation types emphasizing preservation of feathers, skeletons, soft tissues, or (increasingly) some combination thereof. Modern collections range in size from small teaching collections, such as one might find at a nature reserve visitor center or small college, to large research collections of the world's major natural history museums, the largest of which contain hundreds of thousands of specimens. Bird collections function much like libraries, with specimens arranged in drawers and cabinets in taxonomic order, curated by scientists who oversee the maintenance, use, and growth of collections and make them available for study through visits or loans.

History of bird collections

Origin

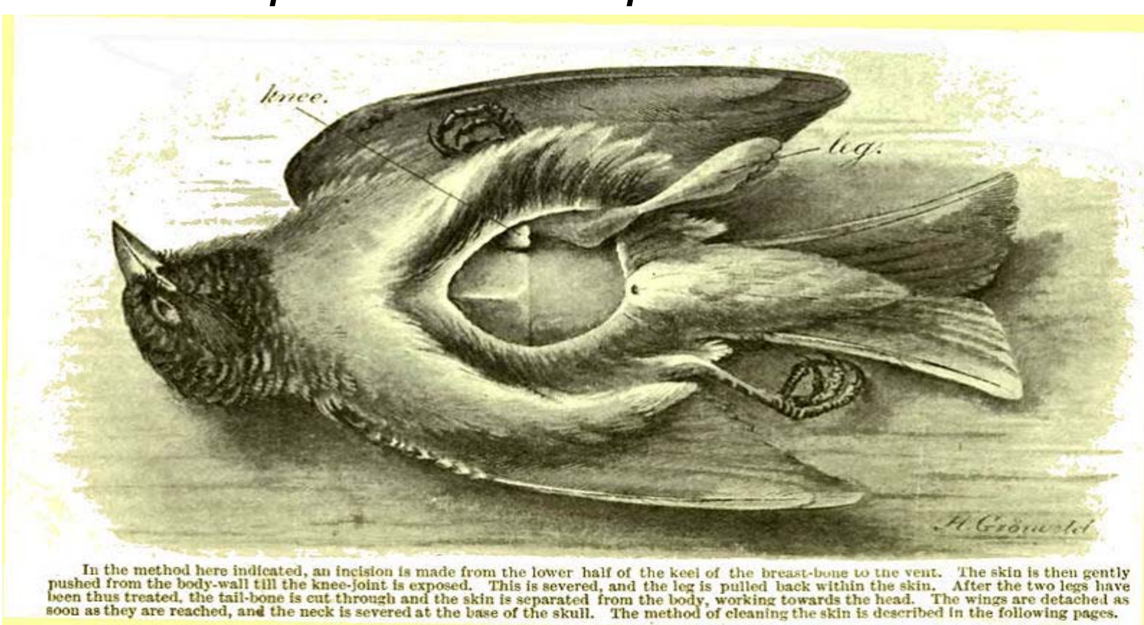
Early collection used life-like mounts like this Red-footed Falcon

The roots of modern bird collections are found in the 18th and 19th century explorations of Europeans intent on documenting global plant and animal diversity. It was a fashion to collect and display *natural curiosities* in Victorian England. Some wealthy *cabinet naturalists* were able to amass large collections using networks of field collectors. These early collections were not intended for scientific study and the collectors gave importance to aesthetics rather than scientific value. It grew into a more scientific pursuit much later.

Growth

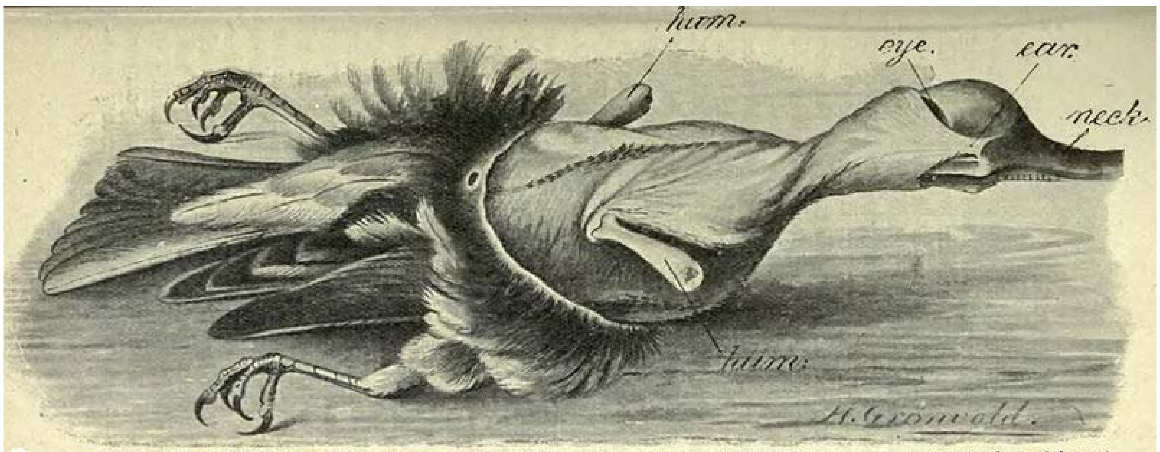
Early scientific bird collections included those belonging to Pallas and Naumann in Germany, Latham and Tunstall in England and Adanson in France. Collections grew in size with increasing maritime activity, exploration and colonialism. For example, Charles Darwin collected over 400 bird specimens during his travels on the *Beagle*, and it was many years after his return to England that his bird collections from the Galapagos inspired (in part) his theory of evolution through natural selection. The Paris museum had 463 bird specimens in 1793 and this grew to 3411 in 1809; The Berlin museum had 2000 specimens in 1813 growing to 13,760 around 1850. The scale of collections grew to the point where they needed more space and full-time curators. In the earliest days of ornithology, collecting was the dominant method of bird observation and study. This approach has diminished with the growth of the discipline. The use of mist-netting and photography, blood sampling (for DNA, immunological and other studies), the development of optics and the use of other new techniques for studying birds have reduced the need to collect specimens for research, yet collections continue to act as a vital shared resource for science (particularly taxonomy) and conservation. In an era of mass extinction, bird collections will evidence lost species.

Collection and preservation techniques



Skinning a bird

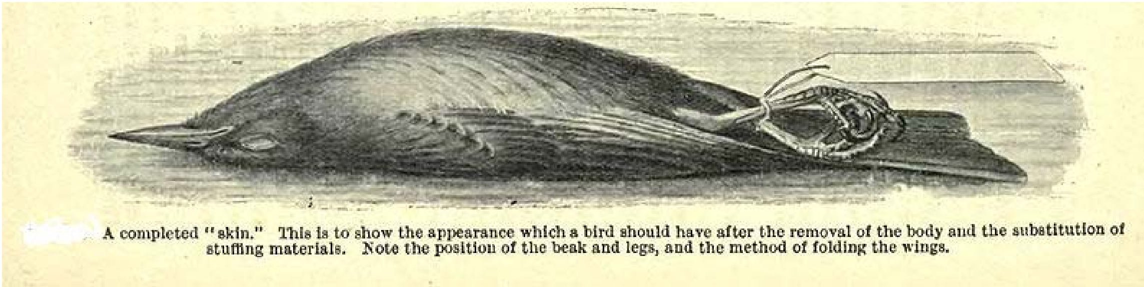
Historically, bird specimens were collected mostly using firearms. Today, specimens come from a variety of sources. Many (perhaps most) are salvaged from birds killed by window and communications tower strikes, domestic cats, by-catch from fisheries, die-offs from disease, vehicle strikes, and other accidental sources of mortality. However, the world's bird collections have been argued to be inadequate in documenting avian diversity, from taxonomic, geographic, and temporal perspectives, with some parts of tropical regions considered under-represented in particular museums. Underrepresented taxa continue to be actively collected by ornithologists, generally using either firearms or mist-nets. Permitting agencies oversee these activities in most countries.



Partially skinned bird, showing the appearance of the skin, now turned inside out. The body has been cut off at the base of the neck. Note the skin still attached to the aperture of the ear, and the position of the eye. *hum* = humerus, or arm-bone.

A partly skinned bird

In the early days of bird collections, most specimens were mounted in unrealistic positions often with their wings raised as if they were about to take flight. These were kept in the open and the colours were prone to fading and the specimens themselves prone to damage by beetles. In Berlin, J. L. Frisch started using tightly enclosed glass jars for every mount to prevent pest damage. During this time, Comte de Reaumur at the Paris Museum had managed to find techniques to preserve specimens without loss of colour. This technique was however a secret and similar results were later achieved by pickling using salt, ground pepper and alum and drying for a month with threads holding the bird in a natural position. In modern collections, salvaged or collected birds may be preserved in a number of ways. The most traditional preparation is a study skin, in which almost all of the body inside the skin is removed and replaced with cotton so that the final result resembles a bird lying on its back with its wings folded. This stereotypic posture was developed to enable many skins to be kept together in cabinets to protect them from insect and light damage. If a complete skeleton is desired, a flat skin may be prepared: all bones, muscle, digestive and other soft tissue is carefully removed and the feathers and skin are stretched flat and dried.



A prepared skin

A more recent preparation method pioneered by the Royal Ontario Museum removes all bones for a complete skeleton while also producing a round skin without bill or legs (called a ROM, though if one set of wing and leg bones remain with the skin the preparation is called a *shmoo* in North America). Alternatively, the entire bird (or any soft parts associated with preparations described above) may be preserved in alcohol. For any of these methods, several supplemental preparations may be made. For example, a wing may be removed and preserved separately as a spread wing for better study of flight feathers; a tissue sample may be removed and frozen for molecular analyses; or a recording of the bird's song before collection may be archived. Neither molecular samples nor sound recordings require a bird to be collected (killed). Finally, if the bird is too rotten for the skin and feathers to be preserved, as is the case with some salvaged specimens, the skeleton alone may be preserved. Dried tissue is removed from skeletons by using dermestid beetle larvae (genus *Dermestes*). Whereas in the past arsenic was routinely added to skins to protect them from destruction by insects, specimens prepared today are generally protected by an initial freezing period to kill insects and their eggs followed by keeping them in high-quality museum cases in a climate-controlled room. Each specimen has data associated with it, and the amount of data available is usually directly correlated with the specimen's scientific value. Most specimens are of little value for research without accompanying information, such as the time and place the bird was found or collected. This and other important information, such as mass, sex, fat deposition, and degree of skull ossification, is written on a label along with a unique field and museum number. Modern computerized museum databases include all of this information for each specimen, as well as the types of methods used to prepare the bird. Modern collections seek to maximize the utility of each preserved individual, and this includes recording detailed information about it. Most modern specimens also include a tissue sample preserved for genetic study. Online access to collections' data is becoming increasingly available, and a cross-institutional database covering millions of computerized bird records is in development.

Uses of bird collections

Study skins of *Garrulus glandarius* in Museum für Naturkunde, Berlin

Bird collections are used for a wide variety of purposes. All biological species including those of birds are represented by a holotype, the vast majority of which are full specimens (mostly skins) and in modern times explicitly designated in the original description of the taxon. All other putative members of the species may be compared to the holotype to confirm their identification. Rigorous studies of avian taxonomy are based on specimens from bird collections. Taxonomic studies rely on unique similarities in morphological and genetic characters to determine species limits and evolutionary relationships. Museum specimens have been the preferred source for scoring these characteristics, as they provide a method for allowing studies to be replicated – anyone may go back and repeat the study using the same specimens to verify the conclusions.

In the case of molecular studies, the preservation of a specimen that can vouch for the source of the tissue sample used to gather genetic data has been recommended, as genetic analysis often yields surprising results that make reexamination of the original specimen crucial.

Studies on ectoparasites, usually obtained during capture, but also obtained from old museum specimens, are valuable for studies on coevolution and zoonoses. However, it has alternatively been argued that such re-examimation can be undertaken from archived photographs without killing the study piece.

In addition to taxonomic research, collections can provide information relevant to the study of variety of other ornithological questions, including comparative anatomy, ecology, behavior, disease, and conservation. Forensic ornithologists use collections to identify species involved in aircraft bird strikes, imported materials containing bird parts, and birds killed through various human activities, legal and illegal. In addition, collections are used by zooarchaeologists to identify bird bones at prehistoric human sites or species of origin for feathers used in human cultural artifacts. Collections also have been heavily used by artists, particularly for the production of plates for ornithological field guides. The close-up observation and opportunity for manipulation provided by preserved study skins makes them, together with field observations and photography, to be an important basis for painters of field guide plates of birds. Most bird species have several unique plumages that distinguish immature from adults, males from females, and breeders from non-breeders. Thus, many different specimens may be required to produce a thorough plate for identification of a given species. Accurate colour measurements using spectrometry are possible from specimens.

Bird collections are becoming increasingly important for use in retrospective studies. Bird collections offer the scientists of today their single opportunity for in-depth morphological and molecular study of past avian diversity. One of the earliest and most famous examples of this was the use of egg collections from the 19th and early 20th centuries in determining that the pesticide DDT was producing eggshell-thinning in raptors. The ornithologists who collected the eggs could never have known that their work would one day help rescue several raptors from possible extinction.

As threats to bird populations grow and extinctions continue, historical specimens are valuable in documenting the impacts of human activities and causes of decline for threatened species. Other possible uses for bird specimens not known today may arise in the future.

Collection debates

The issue of whether birds should continue to be actively collected for research has been the subject of some debate among ornithologists (examples of this can be found in the lively exchanges between Remsen and Bekoff & Elzanowski, between Vuilleumier and Donegan and between Dubois & Nemesio and Donegan). Those opposed to collecting believe that much of current collecting is unnecessary, arguably motivated by the personal field scores of individuals or by competition between museums, rather than the result of a strict scientific rationale; that collecting, in extreme cases of species on the verge of extinction, can pose a threat to bird populations; and that in many cases in which the *necessity* of specimens is claimed, new technology such as digital photography and blood sample analysis of mist-netted individuals could instead be used. Finally, at a time of rampant deforestation and species extinctions, scientists and conservationists should take the lead in providing an example to local people not to kill or hunt birds. Where other techniques not involving killing of a bird are feasible, to take a specimen is viewed by some as simply unethical. Proponents of collecting counter-argue that compared to the many millions of birds killed each year by habitat destruction, domestic cats, window strikes, and tower kills, scientists collect only a few thousand birds per year worldwide and populations will quickly recover from an episode of collecting as long as their habitat remains. Supporters of continued collecting also point to the greater scientific utility and legacy of museum specimens compared to blood samples or photographs, and argue that collecting for research offers the only source of avian mortality with a positive outcome for birds in terms of the biological knowledge gained. Although taking small blood samples from wild birds is often viewed as a harmless alternative to collecting, it reduces survival by as much as 33% and does not provide the benefits of a voucher specimen. Scientists have pointed out that bird populations represent renewable resources, and that scientific collecting represents only a tiny and non-additive proportion of annual bird mortality. However, examples exist of species whose extinction was directly contributed to by museum collecting (e.g. Guadalupe Caracara, Ivory-billed Woodpecker).

Chapter- 4

Bird Conservation

The extinction of the Dusky Seaside Sparrow was caused by habitat loss

Bird conservation is a field in the science of conservation biology related to threatened birds. Humans have had a profound effect on many bird species. Over one hundred species have gone extinct in historical times, although the most dramatic human-caused extinctions occurred in the Pacific Ocean as humans colonised the islands of Melanesia, Polynesia and Micronesia, during which an estimated 750-1800 species of bird went extinct. According to Worldwatch Institute, many bird populations are currently declining worldwide, with 1,200 species facing extinction in the next century. The biggest cited reason surrounds habitat loss. Other threats include overhunting, accidental mortality due to structural collisions, long-line fishing bycatch, pollution, competition and predation by nonnative invasive species, oil spills and pesticide use and climate change. Governments, along with numerous conservation charities, work to protect birds in various ways, including legislation, preserving and restoring bird habitat, and establishing captive populations for reintroductions.

Threats to birds

Habitat loss

The most critical threat facing threatened birds is the destruction and fragmentation of habitat. The loss of forests, plains and other natural systems into agriculture, mines, and urban developments, the draining of swamps and other wetlands, and logging reduce potential habitat for many species. In addition the remaining patches of habitat are often too small or fragmented by the construction of roads or other such barriers that cause populations in these fragmented *islands* to become vulnerable to localised extinction. In addition many forest species show limited abilities to disperse and occupy new forest fragments. The loss of tropical rainforest is the most pressing problem, as these forests hold the highest number of species yet are being destroyed quickly. Habitat loss has been implicated in a number of extinctions, including the Ivory-billed Woodpecker (disputed because of "rediscovery"), Bachman's Warbler and the Dusky Seaside Sparrow.

Introduced species

Arctic Foxes introduced to the Aleutian Islands devastated populations of auks; here a Least Auklet has been taken.

Historically the threat posed by introduced species has probably caused the most extinctions of birds, particularly on islands. Ninety percent of historical extinctions have occurred on islands, and most prehistoric human caused extinctions were insular as well. Many island species evolved in the absence of predators and consequently lost many anti-predator behaviours. As humans traveled around the world they brought with them many foreign animals which disturbed these island species. Some of these were unfamiliar predators, like rats, feral cats, and pigs; others were competitors, such as other bird species, or herbivores that degraded breeding habitat. Disease can also play a role; introduced avian malaria is thought to be a primary cause of many extinctions in Hawaii. The Dodo is the most famous example of a species that was probably driven to extinction by introduced species (although human hunting also played a role), other species that were victims of introduced species were the Stephens Island Wren, Poʻo -uli and the Laysan Millerbird. Many species currently threatened with extinction are vulnerable to introduced species, such as the Kōkako, Black Robin, Mariana Crow, and the Hawaiian Duck.

Hunting and exploitation

Humans have exploited birds for a very long time, and sometimes this exploitation has resulted in extinction. Overhunting occurred in some instances with naive species unfamiliar with humans, such as the moa of New Zealand, in other cases it was an industrial level of hunting that led to extinction. The Passenger Pigeon was once the most numerous species of bird alive (possibly ever), overhunting reduced a species that once numbered in the billions to extinction. Hunting pressure can be for food, sport, feathers, or even come from scientists collecting museum specimens. Collection of Great Auks for museums pushed the already rare species to extinction.

The harvesting of parrots for the pet trade has led to many species becoming endangered. Between 1986 and 1988 two million parrots were legally imported into the US alone. Parrots are also illegally smuggled between countries, and rarer species can command high prices.

Hybridisation

Hybridisation may also endanger birds, damaging the gene stock. For example, the American Black Duck has been often reported hybridising with the Mallard, starting a slow decline.

Gamebird hybrids are particularly common and many breeders produce hybrids that may be accidentally or intentionally introduced into the wild.

Other threats

This Black-browed Albatross has been hooked on a long-line.

Birds face a number of other threats. Pollution has led to serious declines in some species. The pesticide DDT was responsible for thinning egg shells in nesting birds, particularly seabirds and birds of prey that are high on the food chain. Seabirds are also vulnerable to oil spills, which destroy the plumage's waterproofing causing the bird to drown or die of hypothermia. Light pollution can also have a damaging effect on some species, particularly nocturnal seabirds such as petrels.

Seabirds face another threat in the form of bycatch; where birds in the water become tangled in fishing nets or hooked on lines set out by long-line fisheries. As many as 100,000 albatrosses are hooked and drown each year on tuna lines set out by long-line fisheries.

Birds are also threatened by high rise buildings, communications towers, and wind farms; an estimated 975 million birds a year are killed this way in the North America alone, according to the American Bird Conservancy. The largest source of human-related bird death is due to glass windows, which kill 100-900 million birds a year. The next largest sources of human caused death are hunting (100+ million), house cats (100 million), cars and trucks (50 to 100 million), electric power lines (174 million), and pesticides (67 million). Birds are also killed in large quantities by flying into communication tower guidelines, usually after being attracted by tower lights. This phenomena is called towerkill and is responsible for 5-50 million birds deaths a year. The presence of towers may seriously impact endangered species living in the vicinity.

Conservation techniques

Scientists and conservation professionals have developed a number of techniques to protect bird species. These techniques have had varying levels of success.

Captive breeding

Captive breeding, or *ex-situ* conservation, has been used in a number of instances to save species from extinction. The principal is to create a viable population of a species in either zoos or breeding facilities, for later reintroduction back into to the wild. As such a captive population can either serve as an insurance against the species going extinct in the wild or as a last ditch effort in situations where conservation in the wild is impossible. Captive breeding has been used to save several species from extinction, the most famous example being the California Condor, a species that declined to less than thirty birds. In order to save the California Condor the decision was made to take every individual left in the wild into captivity. From these 22 individuals a breeding programme began that brought the numbers up to 273 by 2005. An even more impressive recovery was that of the Mauritius Kestrel, which by 1974 had dropped to only four individuals, yet by 2006 the population was 800.

Reintroduction and translocations

Reintroductions of captive bred populations can occur to replenish wild populations of an endangered species, to create new populations or to restore a species after it has become extinct in the wild. Reintroductions helped bring the wild populations of Hawaiian Geese from 30 birds to over 500. The Mauritius Kestrel was successfully reintroduced into the wild after its captive breeding programme. Reintroductions can be very difficult and often fail if insufficient preparations are made, as species born in captivity may lack the skills and knowledge needed for life in the wild after living in captivity. Reintroductions can also fail if the causes of a birds decline have not been adequately addressed. Attempts to reintroduce the Bali Starling into the wild failed due to continued poaching of reintroduced birds.

The introduction of captives of unknown pedigree can pose a threat to native populations. Domestic fowl have threatened endemic species such as *Gallus g. bankiva* while pheasants such as the Ring-necked Pheasant and captive Cheer pheasants of uncertain origin have escaped into the wild or have been intentionally introduced. Green peafowl of similar mixed origins confiscated from local bird dealers have been released into areas with native wild birds.

Translocations involve moving populations of threatened species into areas of suitable habitat currently unused by the species. There are several reasons for doing this; the creation of secondary populations that act as an insurance against disaster, or in many cases threats faced by the original population in its current location. One famous translocation was of the Kakapo of New Zealand. These large flightless parrots were unable to cope with introduced predators in their remaining habitat on Stewart Island, so were moved to smaller offshore islands that had been cleared of predators. From there a recovery programme has managed to maintain and eventually increase their numbers.

Habitat protection

As the loss and destruction of habitat is the most serious threat facing many bird species, conservation organisations and government agencies tasked with protecting birds work to protect areas of natural habitat. This can be achieved through purchasing land of conservation importance, setting aside land or gazetting it as a national park or other protected area, and passing legislation preventing landowners from undertaking damaging land use practices, or paying them not to undertake those activities. The goals of habitat protection for birds and other threatened animals and plants often conflicts with other stakeholders, such as landowners and businesses, who can face economically damaging restrictions on their activities. Plans to protect crucial habitat for the Spotted Owl of North America required the protection of large areas of old growth forest in the western United States; this was opposed by logging companies who claimed it would cause job losses and reduced profits.

Chapter- 5

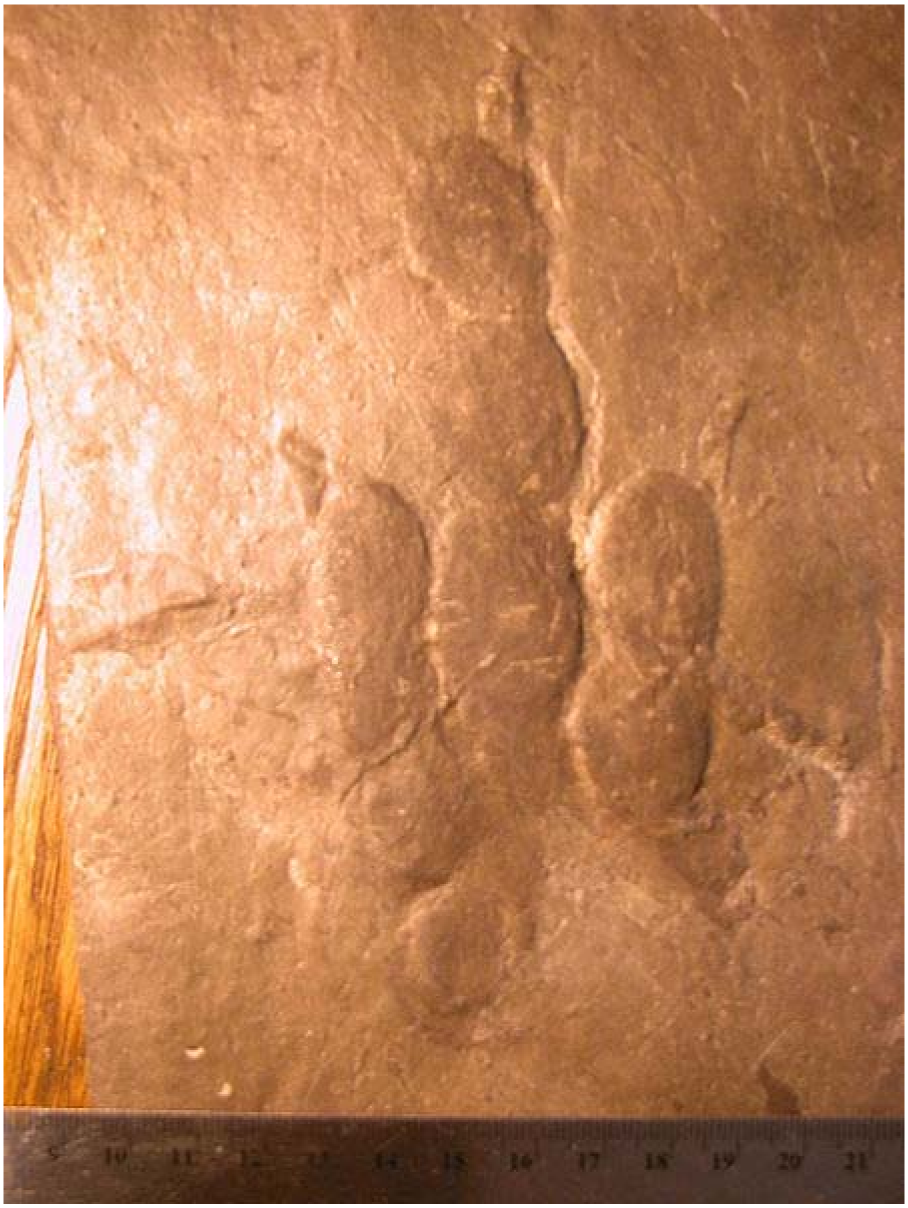
Bird Ichnology

Male Common Teal producing feeding traces on a River Tyne mudflat.

Bird ichnology is the study of avian life traces in ornithology and paleontology. Such life traces can include footprints, nests, feces and coproliths. Scientists gain insight about the behavior and diversity of birds by studying such evidence.

Ichnofossils (or ichnites) are especially important for clarifying the evolution and prehistoric diversity of taxa. These cannot usually be associated with a particular genus, let alone species of bird, as hardly ever they are associated with fossil bones. But it is possible to group them into ichnotaxa based on their morphology (form). In practice, the details of shape that reveal the birds' behavior or biologic affinity are generally given more weight in ichnologic classification.

Bird ichnofossils



Grallator are the footprints of a *Coelophysis*-like theropod, initially mistaken for those of a ratite bird.

Footprints of a large moa found in 1911

Bird footprints typically have a wider angle between the toes. These goose tracks show that webs do not necessarily leave an impression.

These fossil traces of birds are sometimes hard to interpret correctly, especially when they are from the Mesozoic when the birds' dinosaurian relatives were still in existence. Nests at least of Neornithes are usually quite easy to identify as such due to the unique structures of their eggshells; there is some uncertainty as regards the origin of certain Mesozoic eggshells, which makes nests of this age problematic.

Mesozoic fossil footprints are hardest to attribute. "Proto-bird" and related theropod feet were very much alike; non-avian theropod tracks such as the ichnogenus *Grallator* were initially attributed to ratites because in the early 19th century when these were described, the knowledge about dinosaurian diversity was marginal compared to today, whereas ratites were well-known. Also, under the creationist dogma, scientists would believe that e.g. rheas had been around for all eternity. In the Jurassic and Early Cretaceous, juvenile non-avian theropods left very birdlike footprints. Towards the end of the Cretaceous, the tracks of aquatic birds are usually recognizable due to the presence of webbing between the toes; indeed, most avian ichnotaxa fall into this group. However, giant flightless birds also existed by that time, as evidenced by *Gargantuavis*; if the Gastornithidae were indeed close to Anseriformes, their lineage must also have been distinct by then. Such footprints may resemble those of non-avian theropod or even ornithopod dinosaurs. Among the former, the Ornithomimiformes (= "Arctometatarsalia" *sensu stricto*) were convergent to ratites in many respects, including the feet, and it is impossible to tell if some large bird-like footprints from the Late Cretaceous are from an ornithomimiform or a giant bird, without associated bone material.

Footprints

48-million-year-old bird and mammal footprints from the Early Eocene Green River Formation

There exist documented tracks that appear avian since the Late Triassic, by some 55 million years predating the first proper evidence that very birdlike theropods were present. The Late Triassic and early-mid Jurassic tracks have been assigned to the ichnogenera *Trisauropodiscus* and *Aquatilavipes*. Few scientists would go as far though to consider these traces evidence that birds evolved much earlier than generally believed, and perhaps not from theropod dinosaurs as per today's mainstream opinion.

Footprints of at least Neornithes can be distinguished by several features:

- if a hallux is present, it is directed straight backwards or nearly so.
- the second to fourth (front) toes have a wide angle between them (generally 90-180° or so)
- due to Neornithes having a completely fused tarsometatarsus (the "lower leg", actually the ankle and midfoot bones) they have no heel pads (except large terrestrial birds)

It is notable that Heterodontosauridae are known from the localities and times when the first avian-looking footprints started to appear. These small ornithopod dinosaurs were entirely unbirdlike, except for their ornithischian pelvis and a tarsometatarsus strongly convergent to that of Enantiornithes. Though some details remain unresolved, it is far more plausible that *Trisauropodiscus* etc were made by a *Heterodontosaurus*-like animal rather than some sort of bird.

- †*Trisauropodiscus* (Early Jurassic? of Stormberg, South Africa)

  Avian? Non-avian theropod (juvenile *Grallator*)? Heterodontosaurid?

- †*Archaeornithipus* (Late Jurassic/Early Cretaceous of Soria, Spain)

  No hallux; Avian?

- †*Aquatilavipes* (Early Cretaceous of Canada, E Asia ?and South Dakota, USA -? Anacleto Late Cretaceous of Sierra Barrosa, Argentina)

  5-6 x 4-5 cm (h/v). Toes long, narrow, small webs; no or very small hallux; T2-T4 100-140°; toe pads; step 20 cm. Avian: *Patagopteryx*? shorebird?

- †*Fuscinapedis* (Woodbine Early Cretaceous of Denton County, Texas)

  35 x 35 cm (h/v). Toes long, wide; no hallux; T2-T4 110°; toe pads; step 208cm. Avian: giant flightless bird?

- †*Goseongornipes* (Jindong Early? Cretaceous of Goseong County, South Korea) - *Geongsangornipes* is *lapsus*

  4-4.5 x 3-3.5 cm (h/v w/o hallux). Toes long, thin, T3-T4 small webs, T2 shorter; hallux backwards and high; T1-T4 220°; T2-T4 140-150°. Avian: shorebird

- †*Jindongornipes* (Jindong Early? Cretaceous of Goseong County, South Korea)

  6.5-7.5 x 5-6 cm (h/v w/o hallux). Toes long, thin, unwebbed, T2 shorter; hallux backwards, high; T1-T4 225°; T2-T4 95-160°; toe pads. Avian: shorebird

- †*Koreanaornis* (Early Cretaceous of Korea)

  2.5-3.5 x 2.5-3 cm (h/v w/o hallux). Toes long, thin, unwebbed; hallux backwards, high, very small; T1-T4 180; T2-T4 90-135°; toe pads. Avian: shorebird

- †Ichnogen. indet. (Jindong Early? Cretaceous of Goseong County, South Korea)

  2.3 x 3.5 cm (h/v). Toes narrow, unwebbed, T2+T4 shorter; no hallux; T2-T4 75-80°. Avian? perching bird?

- †*Magnoavipes* (Early/Middle Cretaceous of Texas, ?and Israel -? Late Cretaceous of Korea)

  25 x 20 cm (h/v). Toes long, very thin; no hallux; T2-T4 109-118°; step 200-217cm. Avian?

- †*Pullornipes* (Early Cretaceous of China)

  3.3-5.1 x 3.3-4.7 cm (h/v w/o hallux). Toes long, narrow, unwebbed; hallux small, high, backwards and inwards; T1-T4 270-320°, T2-T4 88-141°; step c.15 cm. Avian: shorebird?

- †*Shandongornipes* (Tianjialou Early Cretaceous of Junan County, China)

  6 x 9 cm (h/v). Toes long, thin, unwebbed; hallux backwards, some zygodactyl; T1-T4 220°; T2-T4 135°; toe pads. Avian: cursorial bird

- †*Uhangrichnus* (Haman Early - Uhrangi Late Cretaceous of SW Korea)

  c.4 x 3.7 cm (h/v). Toes long, narrow, fully webbed; no hallux; T2-4 c.100°. Avian: waterbird

- †*Barrosopus* (Anacleto Late Cretaceous of Sierra Barrosa, Argentina)

  3.5 x 3 cm (h/v). Toes narrow, unwebbed, T2 separated (higher); no hallux; T2-T4 100-120°; step 20 cm. Avian?

- †*Sarjeantopodus* (Lance Late Cretaceous of Niobrara County, USA)

  c.9 x 9 cm (h/v). Toes long, thin; hallux backwards; T1-T4 c.215°; T2-T4 c.150°; Toes webbed, no distinct toe pads. Avian: shorebird

- †*Saurexallopus* (Late Cretaceous of WC USA)

  30 x 25-30 cm (h/v). Toes long, thin; hallux sideways; T1-T4 130-170°; T2-T4 90°; deep heel; toe pads. Avian?

- †*Yacoraitichnus* (Late Cretaceous of Quebrada del Tapón, Argentina) – *Yacoriteichnus* is *lapsus*

  No hallux. Avian: enantiornithine? neornithine (galliform)?

- †"Patagonichnornis" (Cretaceous of Ingeniero Jacobacci, Argentina) – *nomen nudum*

  Avian: shorebird?

- †*Iranipeda* (Paleocene of Iran) - may be same as *Gruipeda*
- †*Presbyorniformipes* (Green River Early Eocene of Utah, USA)

  Web impressions present; Avian: presbyornithine?

- †*Charadriipeda* (Late Eocene of France, Spain and USA - Miocene or Romania) – including *Ludicharadripodiscus*

  Web impressions may be present; Avian: anseriform? charadriiform?

- †*Leptoptilostipus* (Liedena Sandstone Late Eocene of S Pyrenees, Spain)

  c.10 x 9 cm (h/v). Toes long, thin, may be partially webbed; hallux small, backwards; T1-T4 190°; T2-T4 130°. Avian: large stork-like wading bird or basal waterfowl.

- †*Ornithoformipes* (Puget Group Late Eocene of Kummer, USA)

  c.27 x 32 cm (h/v). Toes long, wide; no hallux; T2-T4 65°; deep heel; toe pads. May be from *Gastornis*; validity disputed.

- †*Reyesichnus* (Middle Miocene of Salar del Hombre Muerto, Argentina)

  Avian: shorebird?

- †*Avipeda* (Copper Canyon Late Miocene of Califormia, USA)

  Web impressions sometimes present; Avian: waterbirds (Anseriformes, Charadriiformes, Ciconiiformes, Rallidae?)

- †*Roepichnus* (Caños Late Miocene of Almería, Spain)

  Web impressions present; Avian

- †*Anatipeda* (Miocene of Romania)

  Web impressions present; Avian: anseriform?

- †*Gruipeda*

Ichnofamily Ignotornidae

- †*Ignotornis* (Haman Early Cretaceous of Korea - Dakota Sandstone Late Cretaceous of Colorado, USA, ?and Argentina)

6 x 5 cm (h/v w/o hallux). Toes long, narrow, unwebbed or partial small webs, T2 smaller; hallux backwards and high; T1-T4 220°, T2-T4 130-145°; toe pads; step 33 cm. Avian: *Neuquenornis*? shorebird?

- †*Hwangsanipes* (Uhangri Late Cretaceous of South Korea)

  x. 7 x 6 cm (h/v w/o hallux). Toes long, narrow, T2+3 partially, T3+4 fully webbed; hallux large; 1-4 c.225°; T2-4 c.110°. Avian: shorebird

Bird egg fossils (ootaxa)

Fossil eggshells are not actually ichnofossils. As they preserve direct evidence of an organism's physiology, their shape, size and the structure of the eggshell give more robust clues to their origin than do footprints. Typically, fossil eggs can be quite unequivocally assigned to a specific group of organisms, e.g. chelonians, squamates, dinosaurs, crocodiles, pterosaurs or (modern) birds.

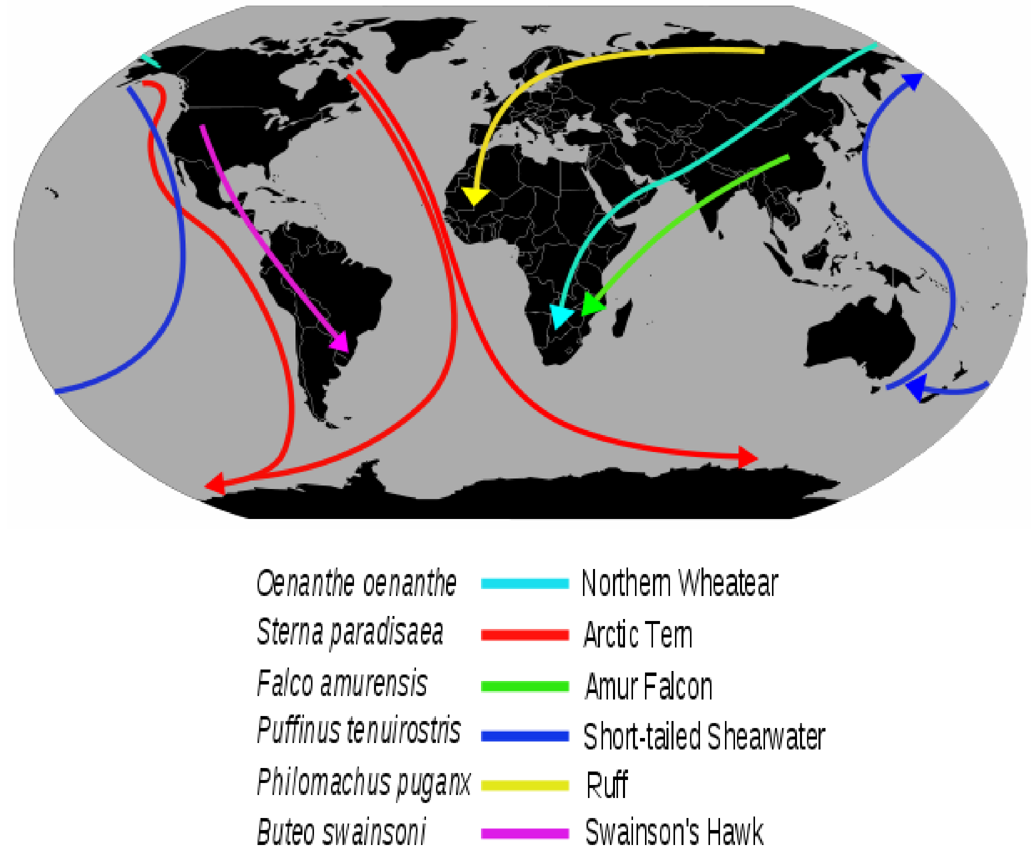
Still, egg fossils rarely are identifiable even to family, let alone to species. Thus, they are assigned to ootaxa, which are much like ichnotaxa but form a distinct group (Veterovata) in parataxonomy. For the time being however, ootaxa assigned to prehistoric birds at least tentatively are listed here:

- † *Oolithus* (Late Jurassic of England) - avian?
- † *Dispersituberoolithus* (Oldman Late Cretaceous of S Alberta, Canada) - neornithine?
- † *Gobioolithus* (Late Cretaceous) - paleognath?
- † *Subtiliolithus* (Late Cretaceous of Mongolia)
- † *Tristraguloolithus* (Oldman Late Cretaceous of S Alberta, Canada) - galliform (cracid)?
- † *Ornitholithus* (Late Paleocene of Spain - Early Eocene of France) - presumably from *Gastornis*
- † *Incognitoolithus* (Eocene of North America) - ratite?
- † Type A ("aepyornithoid") eggs (Tsondab Early Miocene of Namibia - Pliocene of Asia) - ratite?
- † *Namornis* (Middle Miocene of Namibia - Late Miocene of Kenya) - ratite?
- † *Diamantornis* (Middle Miocene of Namibia - Late Miocene of UAE and Kenya) - ratite?
- † *Mediolithus* (Eocene of Germany)
- † *Psammornis* - may be from *Eremopezus* or *Struthio*
- ***Extant genera with named oospecies***
  - *Struthio* - includes *Struthiolithus*

Chapter- 6

Bird Migration

A flock of Barnacle Geese during autumn migration



Some migration routes

Bird migration is the regular seasonal journey undertaken by many species of birds. Bird movements include those made in response to changes in food availability, habitat or weather. Sometimes, journeys are not termed "true migration" because they are irregular (nomadism, invasions, irruptions) or in only one direction (dispersal, movement of young away from natal area). Migration is marked by its annual seasonality. In contrast, birds that are non-migratory are said to be resident or sedentary. Approximately 1800 of the world's 10,000 bird species are long-distance migrants.

General patterns

Many bird populations migrate long distances along a flyway. The most common pattern involves flying north in the spring to breed in the temperate or Arctic summer and returning in the autumn to wintering grounds in warmer regions to the south. Of course, in the Southern Hemisphere the directions are reversed, but there is less land area in the far South to support long-distance migration.

The primary motivation for migration appears to be food; for example, some hummingbirds choose not to migrate if fed through the winter. Also, the longer days of the northern summer provide extended time for breeding birds to feed their young. This helps diurnal birds to produce larger clutches than related non-migratory species that remain in the tropics. As the days shorten in autumn, the birds return to warmer regions where the available food supply varies little with the season.

These advantages offset the high stress, physical exertion costs, and other risks of the migration such as predation. Predation can be heightened during migration: the Eleonora's Falcon, which breeds on Mediterranean islands, has a very late breeding season, coordinated with the autumn passage of southbound passerine migrants, which it feeds to its young. A similar strategy is adopted by the Greater Noctule bat, which preys on nocturnal passerine migrants. The higher concentrations of migrating birds at stopover sites make them prone to parasites and pathogens, which require a heightened immune response.

Within a species not all populations may be migratory; this is known as "partial migration". Partial migration is very common in the southern continents; in Australia, 44% of non-passerine birds and 32% of passerine species are partially migratory. In some species, the population at higher latitudes tends to be migratory and will often winter at lower latitude. The migrating birds bypass the latitudes where other populations may be sedentary, where suitable wintering habitats may already be occupied.

This is an example of *leap-frog migration*. Many fully-migratory species show leap-frog migration (birds that nest at higher latitudes spend the winter at lower latitudes), and many show the alternative, "chain migration" where populations 'slide' more evenly North and South without reversing order.

Within a population, it is common for different ages and/or sexes to have different patterns of timing and distance. Only the female Chaffinches in Scandinavia migrate, with the males staying resident. This has given rise to the latter's specific name of *coelebs*, a bachelor.

Most migrations begin with the birds starting off in a broad front. Often, this front narrows into one or more preferred routes termed flyways. These routes typically follow mountain ranges or coastlines, sometimes rivers, and may take advantage of updrafts and other wind patterns or avoid geographical barriers such as large stretches of open water. The specific routes may be genetically programmed or learned to varying degrees. The routes taken on forward and return migration are often different. A common pattern in North America is clockwise migration, where birds flying North tend to be further West, and flying South tend to shift Eastwards.

Many, if not most, birds migrate in flocks. For larger birds, flying in flocks reduces the energy cost. Geese in a V-formation may conserve 12–20 % of the energy they would need to fly alone. Red Knots *Calidris canutus* and Dunlins *Calidris alpina* were found in radar studies to fly 5 km per hour faster in flocks than when they were flying alone.

Birds fly at varying altitudes during migration. An expedition to Mt. Everest found skeletons of Pintail and Black-tailed Godwit at 5000 m (16,400 ft) on the Khumbu Glacier. Bar-headed Geese have been seen flying over the highest peaks of the Himalayas above 8000 m (29000 ft) even when low passes of 3000 m (10000 ft) were nearby. Seabirds fly low over water but gain altitude when crossing land, and the reverse pattern is seen in landbirds. However most bird migration is in the range of 150 m (500 ft) to 600 m (2000 ft). Bird-hit aviation records from the United States show most collisions occur below 600 m (2000 ft) and almost none above 1800 m (6000 ft).

Bird migration is not limited to birds that can fly. Most species of penguin migrate by swimming. These routes can cover over 1000 km. Blue Grouse *Dendragapus obscurus* perform altitudinal migration mostly by walking. Emus in Australia have been observed to undertake long-distance movements on foot during droughts.

Historical views

The earliest recorded observations of bird migration were 3000 years ago, as noted by Hesiod, Homer, Herodotus, Aristotle and others. The Bible also notes migrations, as in the Book of Job (39:26), where the inquiry is made: "Doth the hawk fly by Thy wisdom and stretch her wings toward the south?" The author of Jeremiah (8:7) wrote: "The stork in the heavens knoweth her appointed time; and the turtledove, and the crane, and the swallow, observe the time of their coming."

Aristotle noted that cranes traveled from the steppes of Scythia to marshes at the headwaters of the Nile. Pliny the Elder, in his *Historia Naturalis*, repeats Aristotle's observations. Aristotle however suggested that swallows and other birds hibernated. This belief persisted as late as 1878, when Elliott Coues listed the titles of no less than 182 papers dealing with the hibernation of swallows. It was not until early in the nineteenth century that migration as an explanation for the winter disappearance of birds from northern climes was accepted.

Long-distance migration

Swainson's Thrush

Northern Pintail

The typical image of migration is of northern landbirds, such as swallows and birds of prey, making long flights to the tropics. Many northern-breeding ducks, geese and swans are also long-distance migrants, but need only to move from their Arctic breeding grounds far enough south to escape frozen waters. Most Holarctic wildfowl species remain in the Northern Hemisphere, but in countries with milder climates. For example, the pink-footed goose migrates from Iceland to Britain and neighbouring countries. Migratory routes and wintering grounds are traditional and learned by young during their first migration with their parents. Some ducks, such as the Garganey, move completely or partially into the tropics.

The same considerations about barriers and detours that apply to long-distance land-bird migration apply to water birds, but in reverse: a large area of land without bodies of water that offer feeding sites is a barrier to a water bird. Open sea may also be a barrier to a bird that feeds in coastal waters. Detours avoiding such barriers are observed: for example, Brent Geese migrating from the Taymyr Peninsula to the Wadden Sea travel via the White Sea coast and the Baltic Sea rather than directly across the Arctic Ocean and northern Scandinavia.

Bar-tailed Godwit

A similar situation occurs with waders (called "shorebirds" in North America). Many species, such as Dunlin and Western Sandpiper, undertake long movements from their Arctic breeding grounds to warmer locations in the same hemisphere, but others such as Semipalmated Sandpiper travel longer distances to the tropics in the Southern Hemisphere. Like the large and powerful wildfowl, the waders are strong fliers. This means that birds wintering in temperate regions have the capacity to make further shorter movements in the event of particularly inclement weather.

For some species of waders, migration success depends on the availability of certain key food resources at stopover points along the migration route. This gives the migrants an opportunity to "refuel" for the next leg of the voyage. Some examples of important stopover locations are the Bay of Fundy and Delaware Bay.

Some Bar-tailed Godwits have the longest known non-stop flight of any migrant, flying 11,000 km from Alaska to their New Zealand non-breeding areas. Prior to migration, 55 percent of their bodyweight is stored fat to fuel this uninterrupted journey.

Arctic Terns

Seabird migration is similar in pattern to those of the waders and waterfowl. Some, such as the Black Guillemot and some gulls, are quite sedentary; others, such as most terns and auks breeding in the temperate northern hemisphere, move varying distances south in the northern winter. The Arctic Tern has the longest-distance migration of any bird, and sees more daylight than any other, moving from its Arctic breeding grounds to the Antarctic non-breeding areas. One Arctic Tern, ringed (banded) as a chick on the Farne Islands off the British east coast, reached Melbourne, Australia in just three months from fledging, a sea journey of over 22,000 km (14,000 miles). A few seabirds, such as Wilson's Petrel and Great Shearwater, breed in the southern hemisphere and migrate north in the southern winter. Seabirds have the additional advantage of being able to feed during migration over open waters.

The most pelagic species, mainly in the 'tubenose' order Procellariiformes, are great wanderers, and the albatrosses of the southern oceans may circle the globe as they ride the "roaring forties" outside the breeding season. The tubenoses spread widely over large areas of open ocean, but congregate when food becomes available. Many are also among the longest-distance migrants; Sooty Shearwaters nesting on the Falkland Islands migrate 14,000 km (9,000 miles) between the breeding colony and the North Atlantic Ocean off Norway. Some Manx Shearwaters do this same journey in reverse. As they are long-lived birds, they may cover enormous distances during their lives; one record-breaking Manx Shearwater is calculated to have flown 8 million km (5 million miles) during its over-50 year lifespan.

Griffon Vulture soaring

Some large broad-winged birds rely on thermal columns of rising hot air to enable them to soar. These include many birds of prey such as vultures, eagles, and buzzards, but also storks. These birds migrate in the daytime. Migratory species in these groups have great difficulty crossing large bodies of water, since thermals only form over land, and these birds cannot maintain active flight for long distances. The Mediterranean and other seas present a major obstacle to soaring birds, which must cross at the narrowest points. Massive numbers of large raptors and storks pass through areas such as Gibraltar, Falsterbo, and the Bosphorus at migration times. More common species, such as the Honey Buzzard, can be counted in hundreds of thousands in autumn. Other barriers, such as mountain ranges, can also cause funnelling, particularly of large diurnal migrants. This is a notable factor in the Central American migratory bottleneck.

Ruby-throated Hummingbird

Many of the smaller insectivorous birds including the warblers, hummingbirds and flycatchers migrate large distances, usually at night. They land in the morning and may feed for a few days before resuming their migration. The birds are referred to as *passage migrants* in the regions where they occur for short durations between the origin and destination.

Nocturnal migrants minimize predation, avoid overheating, and feed during the day. One cost of nocturnal migration is the loss of sleep. Migrants may be able to alter their quality of sleep to compensate for the loss.

Short-distance and altitudinal migration

Cedar Waxwing

Many long-distance migrants appear to be genetically programmed to respond to changing day length. Species that move short distances, however, may not need such a timing mechanism, and may move in response to local weather conditions.

Thus mountain and moorland breeders, such as Wallcreeper and White-throated Dipper, may move only altitudinally to escape the cold higher ground. Other species such as Merlin and Skylark will move further to the coast or to a more southerly region. Species like the Chaffinch are not migratory in Britain, but will move south or to Ireland in very cold weather.

Short-distance passerine migrants have two evolutionary origins. Those that have long-distance migrants in the same family, such as the Chiffchaff, are species of southern hemisphere origins that have progressively shortened their return migration to stay in the northern hemisphere.

Species that have no long-distance migratory relatives, such as the waxwings, are effectively moving in response to winter weather, rather than enhanced breeding opportunities.

Woodland Kingfisher

In the tropics there is little variation in the length of day throughout the year, and it is always warm enough for a food supply (although because of competition, there may not be enough food for every bird). Migration within the tropics has been far less studied than in the temperate zones. It was once assumed that tropical birds were mostly sedentary; however, altitudinal migration and other within-tropics movements appear to be surprisingly common. Many tropical regions have wet and dry seasons, inducing some birds to migrate or wander widely to find food. Indeed, the monsoons of India are preceded by the arrival of the Jacobin Cuckoo, the "harbinger of the monsoon". Other examples include the Woodland Kingfisher of west Africa and many Australian birds.

There are a few species, notably cuckoos, which are genuine long-distance migrants within the tropics. An example is the Lesser Cuckoo, which breeds in India and spends the non-breeding season in Africa. Such examples help make the case that food supplies, not weather per se, drive migration patterns.

Altitudinal migration is common on mountains worldwide, such as in the Himalayas and the Andes. Quite often, altitudinal migration is combined with distance migration; for example, the Himalayan Kashmir Flycatcher and Pied Thrush both move as far south as the highlands of Sri Lanka. Altitudinal migration may even be important to birds living on relatively small islands, such as the Hawaiian Islands, which have high mountains.

Irruptions and dispersal

Sometimes circumstances such as a good breeding season followed by a food source failure the following year lead to irruptions in which large numbers of a species move far beyond the normal range. Bohemian Waxwing and Common Crossbills show this unpredictable variation in annual numbers.

The temperate zones of the southern continents have extensive arid areas, particularly in Australia and western southern Africa, and weather-driven movements are common but not always predictable. A couple of weeks of heavy rain in one part or another of the usually dry centre of Australia, for example, causes dramatic plant and invertebrate growth, attracting birds from all directions. This can happen at any time of year, and, in any given area, may not happen again for a decade or more, depending on the frequency of El Niño and La Niña periods.

Rainbow Bee-eater

Bird migration is primarily, but not entirely, a Northern Hemisphere phenomenon. In the Southern Hemisphere, seasonal migration tends to be much less obvious. There are several reasons for this.

First, the largely uninterrupted expanses of land mass or ocean tend not to funnel migrations into narrow and obvious pathways, making them less obvious to the human observer. Second, at least for terrestrial birds, climatic regions tend to fade into one another over a long distance rather than be entirely separate: this means that rather than make long trips over unsuitable habitat to reach particular destinations, migrant species can usually travel at a relaxed pace, feeding as they go. Short of banding studies it is often not obvious that the birds seen in any particular locality as the seasons change are in fact different members of the same species passing through, gradually working their way north or south.

Many species do in fact breed in the temperate southern hemisphere regions and winter further north in the tropics. The southern African Greater Striped Swallow, and the Australian Satin Flycatcher, Dollarbird, and Rainbow Bee-eater for example, winters well north of their breeding range.

Physiology and control

The control of migration, its timing and response are genetically controlled and appear to be a primitive trait that is present even in non-migratory species of birds. The ability to navigate and orient themselves during migration is a much more complex phenomenon that may include both endogenous programs as well as learning.

Timing

The primary physiological cue for migration are the changes in the day length. These changes are also related to hormonal changes in the birds.

In the period before migration, many birds display higher activity or Zugunruhe (German: *migratory restlessness*) as well as physiological changes such as increased fat deposition. The occurrence of Zugunruhe even in cage-raised birds with no environmental cues (e.g. shortening of day and falling temperature) has pointed to the role of circannual endogenous programs in controlling bird migrations. Caged birds display a preferential flight direction that corresponds with the migratory direction they would take in nature, even changing their preferential direction at roughly the same time their wild conspecifics change course.

In species where there is polygyny and with considerable sexual dimorphism, there is a tendency for males to return earlier to the breeding sites than their females. This is termed as protandry.

Orientation and navigation

The routes of satellite tagged Bar-tailed Godwits migrating north from New Zealand. This species has the longest known non-stop migration of any species, up to 10,200 km (6,300 mi).

Navigation is based on a variety of senses. Many birds have been shown to use a sun compass. Using the sun for direction involves the need for making compensation based on the time. Navigation has also been shown to be based on a combination of other abilities including the ability to detect magnetic fields (magnetoception), use visual landmarks as well as olfactory cues.

Long distance migrants are believed to disperse as young birds and form attachments to potential breeding sites and to favourite wintering sites. Once the site attachment is made they show high site-fidelity, visiting the same wintering sites year after year.

The ability of birds to navigate during migrations cannot be fully explained by endogenous programming, even with the help of responses to environmental cues. The ability to successfully perform long-distance migrations can probably only be fully explained with an accounting for the cognitive ability of the birds to recognize habitats and form mental maps. Satellite tracking of day migrating raptors such as Ospreys and Honey Buzzards has shown that older individuals are better at making corrections for wind drift.

As the circannual patterns indicate, there is a strong genetic component to migration in terms of timing and route, but this may be modified by environmental influences. An interesting example where a change of migration route has occurred because of such a geographical barrier is the trend for some Blackcaps in central Europe to migrate west and winter in Britain rather than cross the Alps.

Migratory birds may use two electromagnetic tools to find their destinations: one that is entirely innate and another that relies on experience. A young bird on its first migration flies in the correct direction according to the Earth's magnetic field, but does not know how far the journey will be. It does this through a radical pair mechanism whereby chemical reactions in special photo pigments sensitive to long wavelengths are affected by the field. Note that although this only works during daylight hours, it does not use the position of the sun in any way. At this stage the bird is similar to a boy scout with a compass but no map, until it grows accustomed to the journey and can put its other facilities to use. With experience they learn various landmarks and this "mapping" is done by magnetites in the trigeminal system, which tell the bird how strong the field is. Because birds migrate between northern and southern regions, the magnetic field strengths at different latitudes let it interpret the radical pair mechanism more accurately and let it know when it has reached its destination. More recent research has found a neural connection between the eye and "Cluster N", the part of the forebrain that is active during migrational orientation, suggesting that birds may actually be able to *see* the magnetic field of the earth.

Vagrancy

Migrating birds can lose their way and occur outside their normal ranges. These can be due to flying past their destinations as in the "spring overshoot" in which birds returning to their breeding areas overshoot and end up further north than intended. Reverse migration, where the genetic programming of young birds fails to work properly, can lead to great rarities turning up as vagrants thousands of kilometres out of range. Certain areas, because of their location, have become famous as watchpoints for migrating birds. Examples are the Point Pelee National Park in Canada, and Spurn in England. Drift migration of birds blown off course by the wind can result in "falls" of large numbers of migrants at coastal sites.

Migration conditioning

It has been possible to teach a migration route to a flock of birds, for example in re-introduction schemes. After a trial with Canada Geese, microlight aircraft were used in the US to teach safe migration routes to reintroduced Whooping Cranes.

Adaptations

Birds need to alter their metabolism in order to meet the demands of migration. The storage of energy through the accumulation of fat and the control of sleep in nocturnal migrants require special physiological adaptations. In addition, the feathers of a bird suffer from wear-and-tear and require to be molted. The timing of this molt - usually once a year but sometimes two - varies with some species molting prior to moving to their winter grounds and others molting prior to returning to their breeding grounds. Apart from physiological adaptations, migration sometimes requires behavioural changes such as flying in flocks to reduce the energy used in migration or the risk of predation.

Evolutionary and ecological factors

Whether a particular species migrates depends on a number of factors. The climate of the breeding area is important, and few species can cope with the harsh winters of inland Canada or northern Eurasia. Thus the partially migratory Blackbird *Turdus merula* is migratory in Scandinavia, but not in the milder climate of southern Europe. The nature of the staple food is also significant. Most specialist insect eaters outside the tropics are long-distance migrants, and have little choice but to head south in winter.

Sometimes the factors are finely balanced. The Whinchat *Saxicola rubetra* of Europe and the Siberian Stonechat *Saxicola maura* of Asia are long-distance migrants wintering in the tropics, whereas their close relative, the European Stonechat *Saxicola rubicola* is a resident bird in most of its range, and moves only short distances from the colder north and east. A possible factor here is that the resident species can often raise an extra brood.

Recent research suggests that long-distance passerine migrants are of South American and African, rather than northern hemisphere, evolutionary origins. They are effectively southern species coming north to breed rather than northern species going south to winter.

Theoretical analyses, summarized by Alerstam (2001), show that detours that increase flight distance by up to 20% will often be adaptive on aerodynamic grounds - a bird that loads itself with food to cross a long barrier flies less efficiently. However some species show circuitous migratory routes that reflect historical range expansions and are far from optimal in ecological terms. An example is the migration of continental populations of Swainson's Thrush, which fly far east across North America before turning south via Florida to reach northern South America; this route is believed to be the consequence of a range expansion that occurred about 10,000 years ago. Detours may also be caused by differential wind conditions, predation risk, or other factors.

Climate change

Large scale climatic changes, as have been experienced in the past, are expected to have an effect on the timing of migration. Studies have shown a variety of effects including timing changes in migration, breeding as well as population variations.

Ecological effects

The migration of birds also aids the movement of other species, including those of ectoparasites such as ticks and lice, which in turn may carry micro-organisms including those of concern to human health. Considerable interest has been taken due to the global spread of avian influenza, however migrant birds have not been found to be a special risk, with import of pet and domestic birds being a greater threat. Some viruses that are maintained in birds without lethal effects, such as the West Nile Virus may however be spread by migrating birds. Birds may also have a role in the dispersal of propagules of plants and plankton.

Some predators take advantage of the concentration of birds during migration. Greater Noctule bats feed on nocturnal migrating passerines. Some birds of prey specialize on migrating waders.

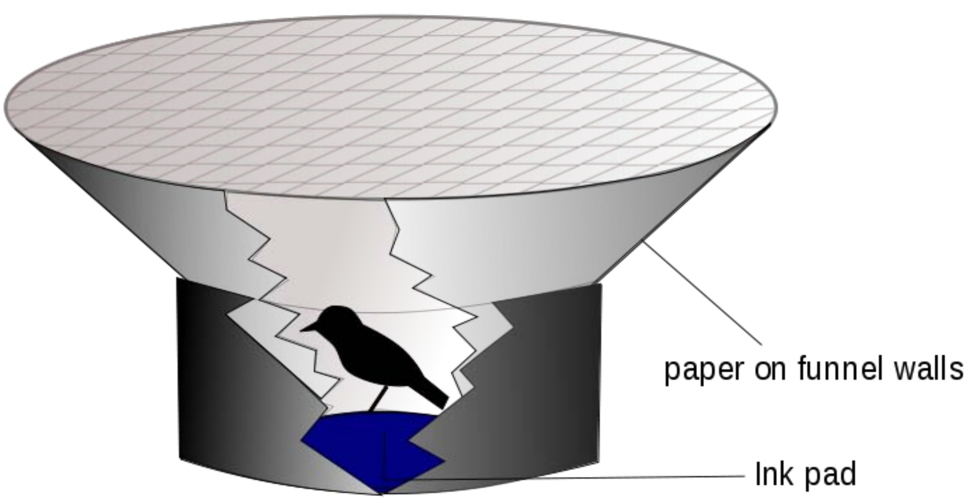
Study techniques

Early studies on the timing of migration began in 1749 in Finland, with Johannes Leche of Turku collecting the dates of arrivals of spring migrants.

Bird migration routes have been studied by a variety of techniques of which ringing is the oldest. Color marking and use of radar, satellite tracking are some of the other techniques.

Stable isotopes of hydrogen, oxygen, carbon, nitrogen, and sulphur have also been used to establish avian migratory connectivity between wintering sites and breeding grounds. Stable isotopic methods to establish migratory linkage rely on spatial isotopic differences in bird diet that are incorporated into inert tissues like feathers, or into growing tissues such as claws and muscle or blood.

An approach to identify migration intensity makes use of upward pointing microphones to record the nocturnal contact calls of flocks flying overhead. These are then analyzed in a laboratory to measure time, frequency and species.



Emlen funnel

An older technique to quantify migration involves observing the face of the moon towards full moon and counting the silhouettes of flocks of birds as they fly at night.

Orientation behaviour studies have been traditionally carried out using variants of a setup known as the **Emlen funnel**, which consists of a circular cage with the top covered by glass or wire-screen so that either the sky is visible or the setup is placed in a planetarium or with other controls on environmental cues. The orientation behaviour of the bird inside the cage is studied quantitatively using the distribution of marks that the bird leaves on the walls of the cage. Other approaches used in pigeon homing studies make use of the direction in which the bird vanishes on the horizon.

Threats and conservation

Human activities have threatened many migratory bird species.The distances involved in bird migration mean that they often cross political boundaries of countries and conservation measures require international cooperation. Several international treaties have been signed to protect migratory species including the Migratory Bird Treaty Act of 1918 of the US and the African-Eurasian Migratory Waterbird Agreement.

The concentration of birds during migration can put species at risk. Some spectacular migrants have already gone extinct, the most notable being the Passenger Pigeon (*Ectopistes migratorius*). During migration the flocks were a mile (1.6 km) wide and 300 miles (500 km) long, taking several days to pass and containing up to a billion birds.

Other significant areas include stop-over sites between the wintering and breeding territories. A capture-recapture study of passerine migrants with high fidelity for breeding and wintering sites did not show similar strict association with stop-over sites.

Hunting along the migratory route can also take a heavy toll. The populations of Siberian Cranes that wintered in India declined due to hunting along the route, particularly in Afghanistan and Central Asia. Birds were last seen in their favourite wintering grounds in Keoladeo National Park in 2002.

Structures such as power lines, wind farms and offshore oil-rigs have also been known to affect migratory birds. Habitat destruction by land use changes is the biggest threat, and shallow wetlands that are stopover and wintering sites for migratory birds are particularly threatened by draining and reclamation for human use.

Chapter- 7

Avian Range Expansion and Bird Colony

Avian range expansion

Avian range expansion describes how birds expand their habitat. Because of the activities of birdwatchers these range expansions are well documented.

Throughout the last century a number of birds have expanded their range. Birds that were once thought to be only located on the West Coast of North America have moved eastward all the way to the East Coast, an example would be the Brewer's Blackbird. Since the 1950's the Brewer's Blackbird, a relative of the Red-Winged Blackbird, has been moving eastward first from the West Coast of Oregon and California to the Great Lakes Region and then towards the East Coast, with the range expanding from Coast to Coast according to the Audubon's 2005 Christmas Bird Count. The Inca Dove first arrived as a native of Mexico and has slowly expanded Northward into Kansas and Arkansas. Great Tailed Grackles have also moved in similar fashion northward. Range expansion may be explained by several different reasons.

Reasons for range expansion

The largest reason for a bird to expand its range is to draw greater resources. Once resources for food, nesting, and potential mates become scarce in a particular area, birds and other animals move out of those areas to find new resources. Range expansion is a crucial component of evolution; however expansions are presently occurring at an alarming rate. One of the reasons for increased expansion is due to human alteration. Human causes such as changing of habitat and global climate change are leading factors in avian range expansion. Species that were previously adapted to the old niche are often replaced by species that are more adapted for newly created niche. For example when forests are replaced by more urban areas, species such as the Inca Dove are replaced by the Mourning Dove, allowing the Mourning Dove to expand its range. Bird populations are not static and naturally change over time. However, due to human effects such as global climate change and loss of habitat, a number of species are expanding in a particular range as the native species they displace are declining. In addition to environmental aspects that cause range expansion and subsequent decline of certain species, humans have introduced species that are largely responsible for decline of native species. Exotic species, such as the European Starling which were introduced by Eugene Schieffelin in 1890 in New York City and then expanded to California by 1955, often do very well in new habitats. The lack of predators and new niche offer perfect conditions for the introduced species to flourish. These "exotic" species often displace other native species. For example the European Starling pursues aggressive breeding strategies that help it colonize new breeding areas. The European Starling is an early breeder and out competes other native cavity nesters for nesting sites. Other cavity nesters include the kestrels, flycatchers, swallows, wrens, and bluebirds. The urbanization of much America also aids in the spread of the European Starling (Podluka et al. 2004, Askins 2000, Elrich et al. 1998).

Examples of when range expansion imperils other species

The Barred Owl and the Northern Spotted Owl

In the 1970's the logging of Old Growth foresting accelerated, and the numbers of the Northern Spotted Owl began to decline. Beginning in 1912 the Barred Owl began expanding its range westward and Northward. Once considered an East Coast Resident, the Barred Owl moved into the Rocky Mountains and Southern Canada, into the Spotted Owls territory. The Barred Owl is extremely adaptable, whereas the Northern Spotted Owl is much more stagnate. The Barred Owl can live in virtually any forest and eat almost anything. The Northern Owl is adapted to best survive in old growth forest and relies mainly on the flying squirrel as a food resource. Much like human counterparts, as the Barred Owl expanded westward these larger more adaptable birds forced native owls, such as the Northern Owl, off their territory. The Barred Owl is about 20% larger and will feast on flying squirrels out of convenience. Biologists have noted a severe decline in the breeding population of Northern Owls, whereas the Barred Owl populations thrive (Levy, 2004).

The Brown-headed Cowbird and other Songbirds

The Brown-headed Cowbird is a brood parasite, which places its own eggs in nest of other birds, placing the burden of parenting on other birds. The Brown-headed Cowbird is thought to have a center of origin in the Great Plains of North America, but has expanded in both directions to spread across most of North America. The behavior of the Brown-headed Cowbird causes range expansion at the expense of other birds such as warblers, sparrows, and vireos. The efforts required for raising the cowbird chick often exhaust the parent and lead to either the death of the parent or the death of the other chicks within the nest, thus decreasing the chances of reproduction for that songbird. In a study conducted by the University of British Columbia, cowbird parasitism was shown to be a direct cause of population declines in Black-capped vireos, Bell's vireo, and the Southwestern willow Flycatcher (Levy, 2004).

Conclusion

Avian species have expanded their range since long before humans. In fact the geographical range of avian species is often a very dynamic phenomenon, with the ranges of various species expanding and some contracting. Range expansions are important because they often signal changing habitats, whether the reason can be explained by natural causes or more often human aided causes. Avian range expansion can produce considerable effects in both the population numbers of the invaded species as well as numbers of hybrid species created. The interaction of invading species and native species is often very dynamic.

Bird colony

A **bird colony** is a large congregation of individuals of one or more species of bird that nest and/or roost in close proximity at a particular location. Many kinds of birds are known to congregate in groups of varying size; a congregation of nesting birds is called a breeding colony. Colonial nesting birds include seabirds such as auks and albatrosses; wetland species such as herons; and a few passerines such as weaverbirds, certain blackbirds, and some swallows. A group of birds congregating for rest is called a communal roost.

A nesting colony of Albatrosses on Laysan island. Early 1900s.

Variations on colonial nesting in birds

Approximately 13% of all bird species nest colonially.

Nesting colonies are very common among seabirds on cliffs and islands. Nearly 95% of seabirds are colonial, leading to the usage, **seabird colony**, sometimes called a rookery. Many species of terns nest in colonies on the ground. Herons, egrets, storks, and other large waterfowl also nest communally in what are called heronries. Colony nesting may be an evolutionary response to a shortage of safe nesting sites and abundance or unpredictable food sources which are far away from the nest sites. Colony-nesting birds often show synchrony in their breeding, meaning that chicks all hatch at once, with the implication that any predator coming along at that time would find more prey items than it could possibly eat.

Common Murre colony (Farallon Islands)

What exactly constitutes a colony is a matter of definition. Tufted Puffins, for example, are pelagic birds that nest on the steep slopes and rocky crevices on coastal cliffs, often on islands. Each pair excavates its own burrow. A congregation of puffin burrows on a marine island is considered a colony. Sand Martins (called Bank Swallows in North America) are seldom, if ever, observed to nest in solitude; such a dependence on social nesting would term the bird a colonial nester. A more extreme example of colonial nesting is found in the weaverbird family. The Sociable Weaver of southern Africa constructs massive, multi-family dwellings of twigs and dry grasses, with many entrances leading to different nesting chambers, accommodating as many as a hundred nesting pairs. These structures resemble haystacks hanging from trees, and have been likened to apartment buildings or beehives.

Some seabird colonies host thousands of nesting pairs of various species. Triangle Island, for example, the largest seabird colony in British Columbia, Canada, is home to auks, gulls, cormorants, shorebirds, and other birds, as well as some marine mammals. Many seabirds show remarkable site fidelity, returning to the same burrow, nest or site for many years, and they will defend that site from rivals with great vigour. This increases breeding success, provides a place for returning mates to reunite, and reduces the costs of prospecting for a new site. Young adults breeding for the first time usually return to their natal colony, and often nest very close to where they hatched. Individual nesting sites at seabird colonies can be widely spaced, as in an albatross colony, or densely packed like an auk colony. In most seabird colonies several different species will nest on the same colony, often exhibiting some niche separation. Seabirds can nest in trees (if any are available), on the ground (with or without nests), on cliffs, in burrows under the ground and in rocky crevices. Colony size is a major aspect of the social environment of colonial birds.

Some birds are known to nest in colonies when conditions are suitable, but not always. The White-winged Dove of southwestern North America was known to nest in large colonies when foraging areas could support such numbers. In 1978, in Tamaulipas, Mexico, researchers counted 22 breeding colonies of White-winged Doves with a collective population size of more than eight million birds. But as habitat was transformed through urbanization and/or agriculture, the doves apparently spread out into smaller, less long-lived colonies. Today, these doves are observed to nest singly and colonially in both urban and rural areas.

The term colony has also been applied, perhaps misleadingly, to smaller nesting groups, such as forest-dwelling species that nest socially in a suitable stand of trees. The Red-cockaded Woodpecker, an endangered species of southeastern North America, is a social species that feeds and roosts in family groups, or clans. Clans nest and roost in clusters of tree cavities and use a cooperative breeding system. Many parrot species are also extremely social. For example, the Thick-billed Parrot is another bird that nests and roosts communally; individuals of neighboring roosts has been observed to communicate with each other each morning to signal their readiness to form flocks for foraging. However, these complex social structures in birds are a different sort of group behavior than what is normally considered colonial.

Ecological functions

The habit of nesting in groups is believed to provide better survival against predators in several ways. Many colonies are situated in locations that are naturally free of predators. In other cases, the presence of many birds means there are more individuals available for defense. Also, synchronized breeding leads to such an abundance of offspring as to satiate predators.

For seabirds, colonies on islands have an obvious advantage over mainland colonies when it comes to protection from terrestrial predators. Other situations can also be found where bird colonies avoid predation. A study of Yellow-rumped Caciques in Peru found that the birds, which build enclosed, pouch-like nests in colonies of up to one hundred active nests, situate themselves near wasp nests, which provide some protection from tree-dwelling predators such as monkeys. When other birds came to rob the nests, the caciques would cooperatively defend the colony by mobbing the invader. Mobbing, clearly a group effort, is well-known behavior, not limited to colonial species; the more birds participating in the mobbing, the more effective it is at driving off the predator. Therefore, it has been theorized that the larger number of individuals available for vigilance and defense makes the colony a safer place for the individual birds nesting there. More pairs of eyes and ears are available to raise the alarm and rise to the occasion.

Another suggestion is that colonies act as information centers and birds that have not found good foraging sites are able to follow others, who have fared better, to find food. This makes sense for foragers because the food source is one that can be locally abundant. This hypothesis would explain why the Lesser Kestrel, which feeds on insects, breeds in colonies, while the related Common Kestrel, which feeds on larger prey, is not.

Colonial behaviour has its costs as well. It has been noted that parasitism by haematozoa is higher in colonial birds and it has been suggested that blood parasites might have shaped adaptations such as larger organs in the immune system and life-history traits. Other costs include brood parasitism and competition for food and territory. Colony size is a factor in the ecological function of colony nesting. In a larger colony, increased competition for food can make it harder for parents to feed their chicks.

The benefits and drawbacks for birds of nesting in groups seem to be highly situational. Although scientists have hypothesized about the advantages of group nesting in terms of enabling group defensive behavior, escape from predation by being surrounded by neighbors (called the selfish herd hypothesis), as well as escaping predators through sheer numbers, in reality, each of these functions evidently depends on a number of factors. Clearly, there can be safety in numbers, but there is some doubt about whether it balances out against the tendency for conspicuous breeding colonies to *attract* predators, and some suggest that colonial breeding can actually make birds more vulnerable. At a Common Tern colony in Minnesota, a study of Spotted Sandpipers observed to nest near the tern colony showed that the sandpipers that nested nearest the colony seemed to gain some protection from mammalian predators, but avian predators were apparently attracted to the colony and the sandpipers nesting there were actually more vulnerable. In a study of a Least Tern colony in Connecticut, nocturnal avian predators in the form of Black-crowned Night Herons and Great Horned Owls were observed to repeatedly invade a colony, flying into the middle of the colony and meeting no resistance.

For seabirds, the location of colonies on islands, which are inaccessible to terrestrial predators, is an obvious advantage. Islands where terrestrial predators have arrived in the form of rats, cats, foxes, etc., have devastated island seabird colonies. One well-studied case of this phenomenon has been the effect on Common Murre colonies on islands in Alaska, where foxes were introduced for fur farming.

Human use

By permission of the Hon. Walter Rothschild] [*Tring.*

CARTING ALBATROSS EGGS ON THE ISLAND OF LAYSAN.

At one time these birds were protected ; as this pnotograpn testifies, this is no longer the case.

Eggs collected from a nesting bird colony on Laysan island. Early 1900s.

Colony-nesting birds have been used by humans as a source of food in the form of eggs and meat, down for bedding, feathers for quill pens, and guano for fertilizer. Over-exploitation can be devastating to a colony, or even to an entire population of a colonial species. For example, there was once a large seabird known as the Great Auk, which nested in colonies in the North Atlantic. Eggs and birds were used for a variety of purposes. Beginning in the 16th Century, seafarers took the birds in especially great numbers to fill ships' larders, and by the mid-19th century, the Great Auk was extinct. Likewise, the Short-tailed Albatross of the North Pacific was heavily harvested at what seems to have been its primary colony on Torishima Island. Millions of birds were killed with a few decades at the end of the 19th century. It survives, though endangered. In North America, the case of the highly gregarious Passenger Pigeon has been well-documented. It was hunted as if inexhaustible. Case in point: in 1871, in Wisconsin, an estimated 136 million pigeons nested in a dense congregation over a wide area; thousands of people were drawn to hunt the birds, shipping the squab to market by rail. The Passenger Pigeon is a famous example of a familiar bird going extinct in modern times.

The use of seabird droppings as fertilizer, or guano, began with the Indigenous Peruvians, who collected it from sites along the coast of South America, such as the Chincha Islands. When, after the Spanish Conquest, the value of this fertilizer became known to the wider world, collection increased to the point where the supply nearly ran out, and other sources of guano had to be found.

Nesting gannets (*Morus serrator*) at the Muriwai colony in [New Zealand]

A colony of Sooty Terns (Onychoprion fuscatus) on on Cook Islet, Kiritimati, Line Islands, Kiribati.

A dense colony of Sandwich Terns (Sterna sandvicensis)

Seabird colony with Great Frigatebird, Red-tailed Tropicbird, Red-footed Booby, Sooty Tern and Black Noddy. Tern Island, French Frigate Shoals, Northwestern Hawaiian Islands

Monk Parakeet nest colony

Sociable Weaver nests

Red-rumped Cacique nest colony by a river

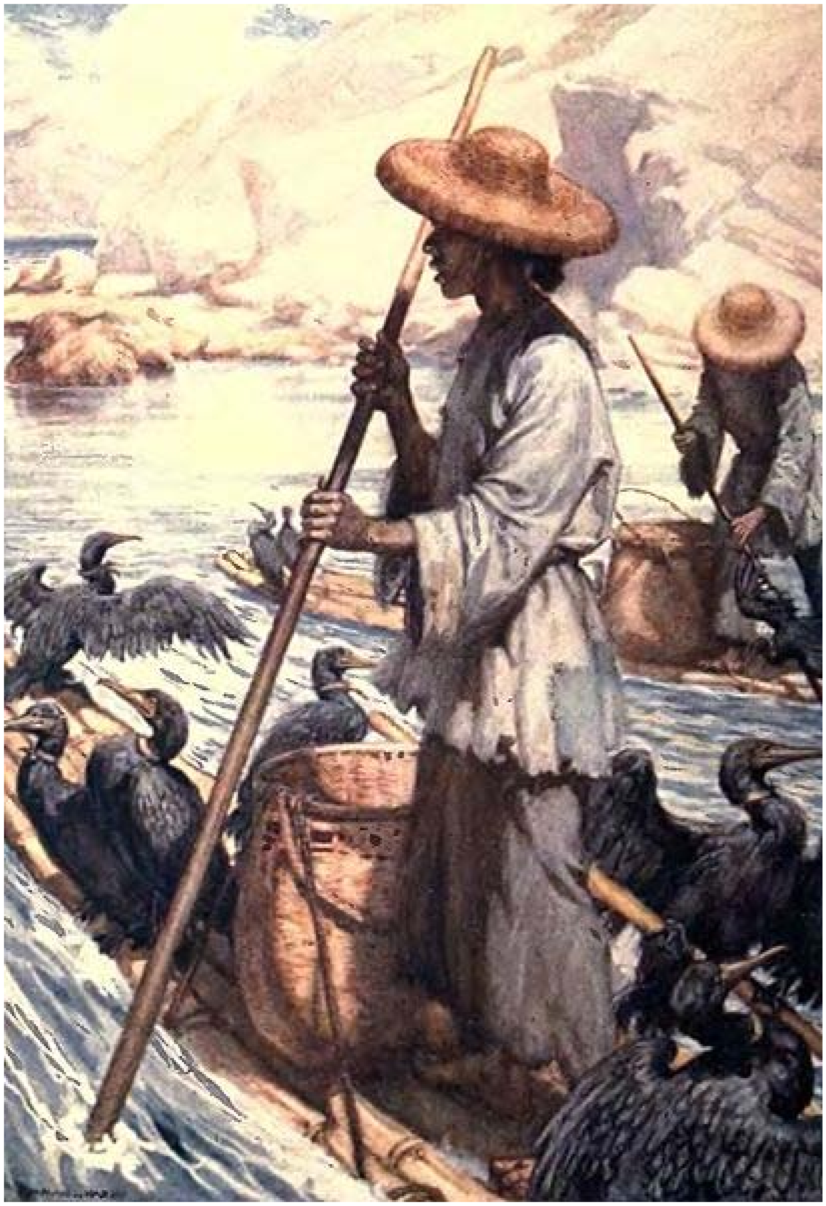
Nest holes of Sand Martins.

Chapter- 8

Bird Intelligence

Bird intelligence deals with the definition of intelligence and its measurement as it applies to birds. Traditionally, birds have been considered inferior in intelligence to mammals, and derogatory terms such as *bird brains* have been used colloquially in some cultures. Such perceptions are no longer considered scientifically valid. The difficulty of defining or measuring intelligence in non-human animals makes the subject difficult for scientific study. Anatomically, birds have a relatively large brain compared to head size. The visual and auditory senses are well developed in most species, while tactile and olfactory senses are well developed only in a few groups. Locomotion is achieved through flight and use of the legs in most species. The beak and feet are used to manipulate food and other objects. Birds can communicate using visual signals as well as through the use of calls and song. The testing of intelligence is therefore based on studying the responses to sensory stimuli.

Studies



Cormorants used by fishermen in Southeast Asia may be able to count

Bird intelligence has been studied through several attributes and abilities. Many of these studies have been on birds such as quail, domestic fowl and pigeons kept under captive conditions. It has, however, been noted that field studies have been limited, unlike those of the apes. Birds such as the corvids and psittacines have been shown to live social lives, have long developmental periods and large forebrains, and these may be expected to have greater cognitive abilities.

Counting

Counting has been considered an ability that shows intelligence. Early anecdotal evidence has suggested that crows may count up to 3. Researchers however need to be cautious and ensure that birds are not merely demonstrating the ability to subitize. Some studies have suggested that crows may indeed have a true numerical ability. Parrots have been shown to count up to 6.

Cormorants used by Chinese fishermen that were given every eighth fish as a reward were found to be able to keep count up to eight.

In the 1970s, on the Li River, Pamela Egremont observed fishermen who allowed the birds to eat every eighth fish they caught. Writing in the Biological Journal of the Linnean Society, she reported that, once their quota of seven fish was filled, the birds "stubbornly refuse to move again until their neck ring is loosened. They ignore an order to dive and even resist a rough push or a knock, sitting glum and motionless on their perches." Meanwhile, other birds that had not filled their quotas continued to catch fish as usual. "One is forced to conclude that these highly intelligent birds can count up to seven," she wrote.
—Hoh, E. H.

Many birds are also able to detect changes in the number of eggs in their nest and brood. Parasitic cuckoos are often known to remove one of the host eggs before laying their own.

Associative learning

Visual or auditory signals and their association with food and other rewards have been well studied and birds have been trained to recognize and distinguish complex shapes. This is probably an important ability that aids their survival.

Spatial and temporal abilities

A common test of intelligence is the detour test. Here a glass barrier between the bird and an item such as food is used in the setup. Most mammals discover that the objective is reached by first going away from the target. Domestic fowl fail on this test. Many corvids were found to readily solve the problem.

Large fruit-eating birds in tropical forests depend on trees which fruit at different times of the year. Many species, such as pigeons and hornbills, have been shown to be able to decide upon foraging areas according to the time of the year. Birds that show food caching behaviour have also shown the ability to recollect the locations of food caches. Nectarivorous birds such as hummingbirds also optimize their foraging by keeping track of the locations of good and bad flowers. Studies of Western Scrub Jays (*Aphelocoma californica*) also suggests that birds may be able to plan for the future. They cache food according to future needs and risk of not being able to find the food on subsequent days.

Many birds follow strict time schedules in their activities. These are often dependent upon environmental cues. Birds also are sensitive to daylight length, and this awareness is especially important as a cue for migratory species. The ability to orient themselves during migrations is attributed to birds' superior sensory abilities, rather than to intelligence.

Tool use

Many birds have been shown capable of using tools. The definition of a tool has been debated with no consensus being reached. One proposed definition of tool use has been defined as

the use of physical objects other than the animal's own body or appendages as a means to extend the physical influence realized by the animal
—Jones and Kamil, 1973

By this definition, a Lammergeier dropping a bone on a rock would not be using a tool since the rock cannot be seen as an extension of the body. However the use of a rock manipulated using the beak to crack an ostrich egg would qualify the Egyptian vulture as a tool user. Many other species, including parrots, corvids and a range of passerines, have been noted as tool users.

New Caledonian Crows have been observed in the wild to use stick tools with their beaks to extract insects from logs. While young birds in the wild normally learn this technique from elders, a laboratory crow named "Betty" improvised a hooked tool from a wire with no prior experience. The Woodpecker Finch from the Galapagos Islands also uses simple stick tools to assist it in obtaining food. In captivity, a young Cactus Finch learned to imitate this behaviour by watching a woodpecker finch in an adjacent cage. Crows in urban Japan have innovated a technique to crack hard-shelled nuts by dropping them onto crosswalks and letting them be run over and cracked by cars. They then retrieve the cracked nuts when the cars are stopped at the red light. Striated Herons (*Butorides striatus*) use bait to catch fish.

Observational learning

Learning using rewards to reinforce responses is often used in laboratories to test intelligence. However, the ability of animals to learn by observation and imitation is considered more significant. Crows have been noted for their ability to learn from each other.

Brain anatomy

At the beginning of the 20th century, scientists argued that the birds had hyper-developed basal ganglia, with tiny mammalian-like telencephalon structures. Modern studies have refuted this view The basal ganglia only occupy a small part of the avian brain. Instead, it seems that birds use a different part of their brain, the medio-rostral neostriatum/hyperstriatum ventrale, as the seat of their intelligence, and the brain-to-body size ratio of psittacines and corvines is actually comparable to that of higher primates.

Studies with captive birds have given insight into which birds are the most intelligent. While parrots have the distinction of being able to mimic human speech, studies with the African Grey Parrot have shown that some are able to associate words with their meanings and form simple sentences. Along with parrots, the crows, ravens, and jays (family Corvidae) are perhaps the most intelligent of birds. Not surprisingly, research has shown that these species tend to have the largest HVCs. Dr. Harvey J. Karten, a neuroscientist at UCSD who has studied the physiology of birds, has discovered that the lower parts of avian brains are similar to those of humans.

Social behaviour

Social life has been considered to be a driving force for the evolution of intelligence. Many birds have social organizations, and loose aggregations are common. Many corvid species separate into small family groups (or "clans") for activities such as nesting and territorial defense. The birds then congregate in massive flocks made up of several different species for migratory purposes. Some birds use teamwork while hunting. Predatory birds hunting in pairs have been observed using a "bait and switch" technique, whereby one bird will distract the prey while the other swoops in for the kill.

Social behaviour requires individual identification, and most birds appear to be capable of recognizing mates, siblings and young. Other behaviours such as play and cooperative breeding are also considered indicators of intelligence.

When crows are caching food, they appear to be sensitive to note who is watching them hide the food. They also steal food caught by others.

In some fairy-wrens such as the Superb and Red-backed, males pick flower petals in colors contrasting with their bright nuptial plumage and present them to others of their species that will acknowledge, inspect and sometimes manipulate the petals. This function seems not linked to sexual or aggressive activity in the short and medium term thereafter, though its function is apparently not aggressive and quite possibly sexual.

Language

Birds communicate with their flockmates through song, calls, and body language. Studies have shown that the intricate territorial songs of some birds must be learned at an early age, and that the memory of the song will serve the bird for the rest of its life. Some bird species are able to communicate in a variety of dialects. For example, the New Zealand saddleback will learn the different song "dialects" of clans of its own species, much as human beings might learn diverse regional dialects. When a territory-owning male of the species dies, a young male will immediately take his place, singing to prospective mates in the dialect appropriate to the territory he is in.

Recent studies indicate that some birds may have an ability to understand grammatical structures.

Conceptual abilities

Evidence that birds can form abstract concepts such as *same–different* has been proven by *Alex*, the African grey parrot. Alex was trained to vocally label more than 100 objects of different colours and shapes and which are made from different materials. Alex could also request or refuse these objects ('I want X') and quantify numbers of them.

It has been noted that bird brainwaves are very similar to that of humans, there are many similarities between the lobes of the brain and most notable the cerebral cortex. For this reason it is believed they can understand human language.

Theory of mind

A study on the Little Green Bee-eater suggests that these birds may be able to see from the point of view of a predator. Such an ability to see from the point of view of another individual had previously been attributed only to the great apes. Such abilities form the basis for empathy. Research conducted with an Eleonora Cockatoo named Snowball has shown that birds can learn to dance to human-made music.

Chapter- 9

Bird Nest

Deep cup nest of the Great Reed-warbler

A **bird nest** is the spot in which a bird lays and incubates its eggs and raises its young. Although the term is popular in reference to a specific structure made by the bird itself—such as the grassy cup nest of the American Robin or Eurasian Blackbird, or the elaborately woven hanging nest of the Montezuma Oropendola, the Village Weaver or the Red-browed Pardalote—that is too restrictive a definition. For some species, a nest is simply a shallow depression made in sand; for others, it is the knot-hole left by a broken branch, a burrow dug into the ground, a chamber drilled into a tree, an enormous rotting pile of vegetation and earth, or a mud dome with an entrance tunnel. Some species of cave swiftlets of the genus *Collocalia* make their nests entirely from their saliva, which dries and hardens to form a bracket on the cave wall into which the birds lay their eggs. The smallest bird nests are those of some hummingbirds, tiny cups which can be a mere 2 cm (less than one inch) across and 2–3 cm (about one inch) high. At the other extreme, some nest mounds built by the Dusky Scrubfowl measure more than 11 m (34 ft) in diameter and stand nearly 5 m (15 ft) tall. Although nests are primarily used for breeding they may also be reused in the non-breeding season for roosting and some species build special *dormitory nests* or *roost nests* (or *winter-nest*) that are used only for roosting.

Nests are built each year in most species but some birds refurbish their old nests. The large **eyries** (or **aeries**) of some eagles are platform nests that have been used and refurbished for several years.

In yet another extreme, brood parasites have evolved to manipulate and use host individuals either of the same or different species to raise the young of the brood-parasite, which relieves the parasitic parent from the building of nests and the investment of rearing young.

In most species, the female does all or most of the nest construction, though the male often helps. In some polygynous species, however, the male may do most or all of the nest building. The nest may also form a part of their courtship display such as in bowerbirds and weaver birds. The ability to choose and maintain good nest sites and build high quality nests may be selected for by females in these species. In some species the young from previous broods may also act as helpers for the adults.

Nest types

Thick-billed Murres lay their single eggs directly onto rock ledges.

Not every bird species builds or uses a nest. Some auks, for instance—including Common Murre, Thick-billed Murre and Razorbill—lay their eggs directly onto the narrow rocky ledges they use as breeding sites. The eggs of these species are dramatically pointed at one end, so that they roll in a circle when disturbed. This is critical for the survival of the developing eggs, as there are no nests to keep them from rolling off the side of the cliff. Presumably because of the vulnerability of their unprotected eggs, parent birds of these auk species rarely leave them unattended.

King and Emperor Penguins also do not build nests; instead, they tuck their eggs and chicks between their feet and folds of skin on their lower bellies. They are thus able to move about while incubating, though in practice only the Emperor Penguin regularly does so. Emperor Penguins breed during the harshest months of the Antarctic winter, and their mobility allows them to form huge huddled masses which help them to withstand the extremely high winds and low temperatures of the season. Without the ability to share body heat (temperatures in the center of tight groups can be as much as 10C above the ambient air temperature), the penguins would expend far more energy trying to stay warm, and breeding attempts would probably fail.

Some crevice-nesting species, including Ashy Storm-petrel, Pigeon Guillemot, Eurasian Eagle-Owl and Hume's Tawny Owl, lay their eggs in the relative shelter of a crevice in the rocks or a gap between boulders, but provide no additional nest material. Potoos lay their single egg directly atop a broken stump, or into a shallow depression on a branch—typically where an upward-pointing branch died and fell off, leaving a small scar or knot-hole. Brood parasites, such as the New World cowbirds, the honeyguides, and many of the Old World and Australasian cuckoos, lay their eggs in the active nests of other species.

Scrape

Shell-lined scrape nest of a *Charadrius* plover

The simplest nest construction is the **scrape**, which is merely a shallow depression in soil or vegetation. This nest type, which typically has a rim deep enough to keep the eggs from rolling away, is sometimes lined with bits of vegetation, small stones, shell fragments or feathers. These materials may help to camouflage the eggs or may provide some level of insulation; they may also help to keep the eggs in place, and prevent them from sinking into muddy or sandy soil if the nest is accidentally flooded. Ostriches, most tinamous, many ducks, most shorebirds, most terns, some falcons, pheasants, quail, partridges, bustards and sandgrouse are among the species that build scrape nests.

Eggs and young in scrape nests — and the adults that brood them — are more exposed to predators and the elements than those in more sheltered nests; they are on the ground and typically in the open, with little to hide them. The eggs of most ground-nesting birds (including those that use scrape nests) are cryptically colored to help camouflage them when the adult is not covering them; the actual color generally corresponds to the substrate on which they are laid. Brooding adults also tend to be well camouflaged, and may be difficult to flush from the nest. Most ground-nesting species have well-developed distraction displays, which are used to draw (or drive) potential predators from the area around the nest. Most species with this type of nest have precocial young, which quickly leave the nest upon hatching.

In cool climates (such as in the high Arctic or at high elevations), the depth of a scrape nest can be critical to both the survival of developing eggs and the fitness of the parent bird incubating them. The scrape must be deep enough that eggs are protected from the convective cooling caused by cold winds, but shallow enough that they and the parent bird are not too exposed to the cooling influences of ground temperatures, particularly where the permafrost layer rises to mere centimeters below the nest. Studies have shown that an egg within a scrape nest loses heat 9% more slowly than an egg placed on the ground beside the nest; in such a nest lined with natural vegetation, heat loss is reduced by an additional 25%. The insulating factor of nest lining is apparently so critical to egg survival that some species — including Kentish Plovers — will restore experimentally-altered levels of insulation to their pre-adjustment levels (adding or subtracting material as necessary) within 24 hours.

Lichen-lined scrape nest of the American Golden-Plover

In warm climates, such as deserts and salt flats, heat rather than cold can kill the developing embryos. In such places, scrapes are shallower and tend to be lined with non-vegetative material (including shells, feathers, sticks and soil), which allows convective cooling to occur as air moves over the eggs. Some species, such as the Lesser Nighthawk and the Red-tailed Tropicbird, help reduce the nest's temperature by placing it in partial or full shade. Others, including some shorebirds, cast shade with their bodies as they stand over their eggs. Some shorebirds also soak their breast feathers with water and then sit on the eggs, providing moisture to enable evaporative cooling. Parent birds keep from overheating themselves by gular panting while they are incubating, frequently exchanging incubation duties, and standing in water when they are not incubating.

The technique used to construct a scrape nest varies slightly depending on the species. Beach-nesting terns, for instance, fashion their nests by rocking their bodies on the sand in the place they have chosen to site their nest, while skimmers build their scrapes with their feet, kicking sand backwards while resting on their bellies and turning slowly in circles. The Ostrich also scratches out its scrape with its feet, though it stands while doing so. Many tinamous lay their eggs on a shallow mat of dead leaves they have collected and placed under bushes or between the root buttresses of trees, and Kagus lay theirs on a pile of dead leaves against a log, tree trunk or vegetation. Marbled Godwits stomp a grassy area flat with their feet, then lay their eggs, while other grass-nesting waders bend vegetation over their nests so as to avoid detection from above. Many female ducks, particularly in the northern latitudes, line their shallow scrape nests with down feathers plucked from their own breasts, as well as with small amounts of vegetation. Among scrape-nesting birds, the Three-banded Courser and Egyptian Plover are unique in their habit of partially burying their eggs in the sand of their scrapes.

Mound

Mound nest of the Malleefowl

Burying eggs as a form of incubation reaches its zenith with the Australasian megapodes. Several megapode species construct enormous **mound** nests made of soil, branches, sticks, twigs and leaves, and lay their eggs within the rotting mass. The heat generated by these mounds, which are in effect giant compost heaps, warms and incubates the eggs. Recent research has shown that much of the nest's heat results from the respiration of thermophilic fungi and other microorganisms rather than fermentation, as had been previously believed. The size of some of these mounds can be truly staggering; several of the largest—which contain more than 100 cubic metres (130 cu yd) of material, and probably weigh more than 50 tons (45,000 kg)—were initially thought to be Aboriginal middens.

In most mound-building species, males do most or all of the nest construction and maintenance. Using his strong legs and feet, the male scrapes together material from the area around his chosen nest site, gradually building a conical or bell-shaped pile. This process can take five to seven hours a day for more than a month. While mounds are typically reused for multiple breeding seasons, new material must be added each year in order to generate the appropriate amount of heat. A female will begin to lay eggs in the nest only when the mound's temperature has reached an optimal level.

Chilean Flamingos with mound nests

Both the temperature and the moisture content of the mound are critical to the survival and development of the eggs, so both are carefully regulated for the entire length of the breeding season (which may last for as long as eight months), principally by the male. Ornithologists believe that megapodes may use sensitive areas in their mouths to assess mound temperatures; each day during the breeding season, the male digs a pit into his mound and sticks his head in. If the mound's core temperature is a bit low, he adds fresh moist material to the mound, and stirs it in; if it is too high, he opens the top of the mound to allow some of the excess heat to escape. This regular monitoring also keeps the mound's material from becoming compacted, which would inhibit oxygen diffusion to the eggs and make it more difficult for the chicks to emerge after hatching. The Malleefowl, which lives in more open forest than do other megapodes, uses the sun to help warm its nest as well—opening the mound at midday during the cool spring and autumn months to expose the plentiful sand incorporated into the nest to the sun's warming rays, then using that warm sand to insulate the eggs during the cold nights. During hot summer months, the Malleefowl opens its nest mound only in the cool early morning hours, allowing excess heat to escape before recovering the mound completely. One recent study showed that the sex ratio of Australian Brush-turkey hatchlings correlated strongly with mound temperatures; females hatched from eggs incubated at higher mean temperatures.

Flamingos make a different type of mound nest. Using their beaks to pull material towards them, they fashion a cone-shaped pile of mud between 15–46 cm (6–18 in) tall, with a small depression in the top to house their single egg. The height of the nest varies with the substrate upon which it is built; those on clay sites are taller on average than those on dry or sandy sites. The height of the nest and the circular, often water-filled trench which surrounds it (the result of the removal of material for the nest) help to protect the egg from fluctuating water levels and excessive heat at ground level. In East Africa, for example, temperatures at the top of the nest mound average some 20°C (40°F) cooler than those of the surrounding ground.

The base of the Horned Coot's enormous nest is a mound built of stones, gathered one at a time by the pair, using their beaks. These stones, which may weigh as much as 450 g (about a pound) each, are dropped into the shallow water of a lake, making a cone-shaped pile which can measure as much as 4 m^2 (43 sq ft) at the bottom and 1 m^2 (11 sq ft) at the top, and 0.6 m (2.0 ft) in height. The total combined weight of the mound's stones may approach 1.5 tons (1,400 kg). Once the mound has been completed, a sizable platform of aquatic vegetation is constructed on top. The entire structure is typically reused for many years.

Burrow

Sand Martin at the entrance of its burrow nest

Soil plays a different role in the **burrow** nest; here, the eggs and young—and in most cases the incubating parent bird—are sheltered under the earth. Most burrow-nesting birds excavate their own burrows, but some use those excavated by other species; Burrowing Owls, for example, sometimes use the burrows of prairie dogs, ground squirrels, badgers or tortoises, China's endemic White-browed Tits use the holes of ground-nesting rodents and Common Kingfishers occasionally nest in rabbit burrows. Burrow nests are particularly common among seabirds at high latitudes, as they provide protection against both cold temperatures and predators. Puffins, shearwaters, some megapodes, motmots, todies, most kingfishers, the Crab Plover, miners and leaftossers are among the species which use burrow nests.

Most burrow nesting species dig a horizontal tunnel into a vertical (or nearly vertical) dirt cliff, with a chamber at the tunnel's end to house the eggs. The length of the tunnel varies depending on the substrate and the species; Sand Martins make relatively short tunnels ranging from 50–90 cm (20–35 in), for example, while those of the Burrowing Parakeet can extend for more than three meters (nearly 10 ft). Some species, including the ground-nesting puffbirds, prefer flat or gently sloping land, digging their entrance tunnels into the ground at an angle. In a more extreme example, the D'Arnaud's Barbet digs a vertical tunnel shaft more than a meter (39 in) deep, with its nest chamber excavated off to the side at some height above the shaft's bottom; this arrangement helps to keep the nest from being flooded during heavy rain. Buff-breasted Paradise-kingfishers dig their nests into the compacted mud of active termite mounds, either on the ground or in trees.

Burrow entrances in European Bee-eater colony

Birds use a combination of their beaks and feet to excavate burrow nests. The tunnel is started with the beak; the bird either probes at the ground to create a depression, or flies toward its chosen nest site on a cliff wall and hits it with its bill. The latter method is not without its dangers; there are reports of kingfishers being fatally injured in such attempts. Some birds remove tunnel material with their bills, while others use their bodies or shovel the dirt out with one or both feet. Female paradise-kingfishers are known to use their long tails to clear the loose soil.

Some crepuscular petrels and prions are able to identify their own burrows within dense colonies by smell. Sand Martins learn the location of their nest within a colony, and will accept any chick put into that nest until right before the young fledge.

Not all burrow-nesting species incubate their young directly. Some megapode species bury their eggs in sandy pits dug where sunlight, subterranean volcanic activity, or decaying tree roots will warm the eggs. The Crab Plover similarly makes use of a burrow nest, the warmth of which allows it to forage away from the nest.

Predation levels on some burrow-nesting species can be quite high; on Alaska's Wooded Islands, for example, river otters munched their way through some 23 percent of the island's Fork-tailed Storm-Petrel population during a single breeding season in 1977. There is some evidence that increased vulnerability may lead some burrow-nesting species to form colonies, or to nest closer to rival pairs in areas of high predation than they might otherwise do.

Cavity

A Northern Flicker protruding from its cavity nest

The **cavity** nest is a chamber, typically in living or dead wood, but sometimes in the trunks of tree ferns or large cacti, including saguaro. In tropical areas, cavities are sometimes excavated in arboreal insect nests. A relatively small number of species, including woodpeckers, trogons, some nuthatches and many barbets, can excavate their own cavities. Far more species—including parrots, tits, bluebirds, most hornbills, some kingfishers, some owls, some ducks and some flycatchers—use natural cavities, or those abandoned by species able to excavate them; they also sometimes usurp cavity nests from their excavating owners. Those species that excavate their own cavities are known as "primary cavity nesters", while those that use natural cavities or those excavated by other species are called "secondary cavity nesters". Both primary and secondary cavity nesters can be enticed to use nest boxes (also known as bird houses); these mimic natural cavities, and can be critical to the survival of species in areas where natural cavities are lacking.

Woodpeckers use their chisel-like bills to excavate their cavity nests, a process which takes, on average, about two weeks. Cavities are normally excavated on the downward-facing side of a branch, presumably to make it more difficult for predators to access the nest, and to reduce the chance that rain floods the nest. There is also some evidence that fungal rot may make the wood on the underside of leaning trunks and branches easier to excavate. Most woodpeckers use a cavity for only a single year. The endangered Red-cockaded Woodpecker is an exception; it takes far longer—up to two years—to excavate its nest cavity, and may reuse it for more than two decades. The typical woodpecker nest has a short horizontal tunnel which leads to a vertical chamber within the trunk. The size and shape of the chamber depends on species, and the entrance hole is typically only as large as is needed to allow access for the adult birds. While wood chips are removed during the excavation process, most species line the floor of the cavity with a fresh bed of them before laying their eggs.

Black Woodpecker youngsters in their cavity nest

Trogons excavate their nests by chewing cavities into very soft dead wood; some species make completely enclosed chambers (accessed by upward-slanting entrance tunnels), while others—like the extravagantly-plumed Resplendent Quetzal—construct more open niches. In most trogon species, both sexes help with nest construction. The process may take several months, and a single pair may start several excavations before finding a tree or stump with wood of the right consistency.

Species which use natural cavities—or old woodpecker nests—sometimes line the cavity with soft material such as grass, moss, lichen, feathers or fur. Though a number of studies have attempted to determine whether secondary cavity nesters preferentially choose cavities with entrance holes facing certain directions, the results remain inconclusive. While some species appear to preferentially choose holes with certain orientations, studies (to date) have not shown consistent differences in fledging rates between nests oriented in different directions.

Cavity-dwelling species have to contend with the danger of predators accessing their nest, catching them and their young inside and unable to get out. They have a variety of methods for decreasing the likelihood of this happening. Red-cockaded Woodpeckers peel bark around the entrance, and drill wells above and below the hole; since they nest in live trees, the resulting flow of resin forms a barrier that prevents snakes from reaching the nests. Red-breasted Nuthatches smear sap around the entrance holes to their nests, while White-breasted Nuthatches rub foul-smelling insects around theirs. Eurasian Nuthatches wall up part of their entrance holes with mud, decreasing the size and sometimes extending the tunnel part of the chamber. Most female hornbills seal themselves into their cavity nests, using a combination of mud (in some species brought by their mates), food remains and their own droppings to reduce the entrance hole to a narrow slit.

Cup

Cup nest of a Common Blackbird

Cup nest of a Redwing, with newly hatched chicks

The **cup** nest is smoothly hemispherical inside, with a deep depression to house the eggs. Most are made of pliable materials—including grasses—though a small number are made of mud. Many passerines and a few non-passerines, including some hummingbirds and some swifts, build this type of nest.

Small bird species in more than 20 passerine families, and a few non-passerines—including most hummingbirds, kinglets and crests in the genus *Regulus*, some tyrant flycatchers and several New World warblers—use considerable amounts of spider silk in the construction of their nests. The lightweight material is strong and extremely flexible, allowing the nest to mold to the adult during incubation (reducing heat loss), then to stretch to accommodate the growing nestlings; as it is sticky, it also helps to bind the nest to the branch or leaf to which it is attached.

Saucer or plate

The **saucer** or **plate** nest, though superficially similar to a cup nest, has at most only a shallow depression to house the eggs.

Platform

The huge platform nest of the Osprey

The **platform** nest is a large structure, often many times the size of the (typically large) bird which has built it. Depending on the species, these nests can be on the ground or elevated. In the case of raptor nests, or **eyries** (also spelt **aerie**), these are often used for many years, with new material added each breeding season. In some cases, the nests grow large enough to cause structural damage to the tree itself, particularly during bad storms where the weight of the nest can cause additional stress on wind-tossed branches.

Pendant

Taveta Golden Weaver building pendant nest

The **pendant** nest is an elongated sac woven of pliable materials such as grasses and plant fibers and suspended from a branch. Oropendolas, caciques, orioles, weavers and sunbirds are among the species that weave pendant nests.

Sphere

The **sphere** nest is a roundish structure; it is completely enclosed, except for a small opening which allows access.

Nest protection and sanitation

Many species of bird conceal their nests to protect them from predators. Some species may choose nest sites that are inaccessible. Some may make specific modifications to keep predators at bay. Bird nests can also act as habitats for other inquiline species which may not affect the bird directly. Birds have also evolved nest sanitation measures to reduce the effects of parasites and pathogens on nestlings.

Some aquatic species such as grebes are very careful when approaching and leaving the nest so as not to reveal the location. Some species will use leaves to cover up the nest prior to leaving.

Ground birds such as plovers may use *broken wing* or *rodent run* displays to distract predators from nests.

Many species attack predators or apparent predators near their nests. Kingbirds attack other birds that come too close. In North America, Northern Mockingbirds, Blue Jays, and Arctic Terns can peck hard enough to draw blood. In Australia, a bird attacking a person near its nest is said to *swoop* the person. The Australian Magpie is particularly well-known for this behavior.

Nests can become home to many other organisms including parasites and pathogens. The excreta of the fledglings also pose a problem. In most passerines, the adults actively dispose the fecal sacs of young at a distance or consume them. This is believed to help prevent ground predators from detecting nests. Young birds of prey however usually void their excreta beyond the rims of their nests. Blowflies of the genus *Protocalliphora* have specialized to become obligate nest parasites with the maggots feeding on the blood of nestlings.

Some birds have been shown to choose aromatic green plant material for constructing nests that may have insecticidal properties, while others may use materials such as carnivore scat to repel smaller predators.

Nesting colony of Montezuma Oropendolas

Some birds use pieces of snake slough in their nests. It has been suggested that these may deter some nest predators such as squirrels.

Colonial nesting

Though most birds nest individually, some species—including seabirds, penguins, flamingos, many herons, gulls, terns, weaver, some corvids and some sparrows—gather together in sizeable colonies. Birds that nest colonially may benefit from increased protection against predation. They may also be able to better utilize food supplies, by following more successful foragers to their foraging sites.

In human culture

Many birds nest close to human habitations and some have been specially encouraged. Nesting White Storks have been protected and held in reverence in many cultures. Nest boxes are often used to encourage cavity nesting birds. The nesting of Peregrine Falcons on tall buildings has captured popular interest. Colonial breeders produce guano which is a valuable fertilizer. The saliva nests of Cave Swiftlets are used to make Bird's nest soup in parts of Southeast Asia.

Some species of birds are also considered nuisances when they nest in the proximity of human habitations. Feral pigeons are often unwelcome and sometimes also considered as a health risk.

The Beijing National Stadium, principal venue of the 2008 Summer Olympics, has been nicknamed "The Bird Nest" because of its architectural design, which its designers likened to a bird's woven nest.

In the Victorian era, naturalists often collected bird's eggs and their nests. The study of bird nests is called *caliology*.

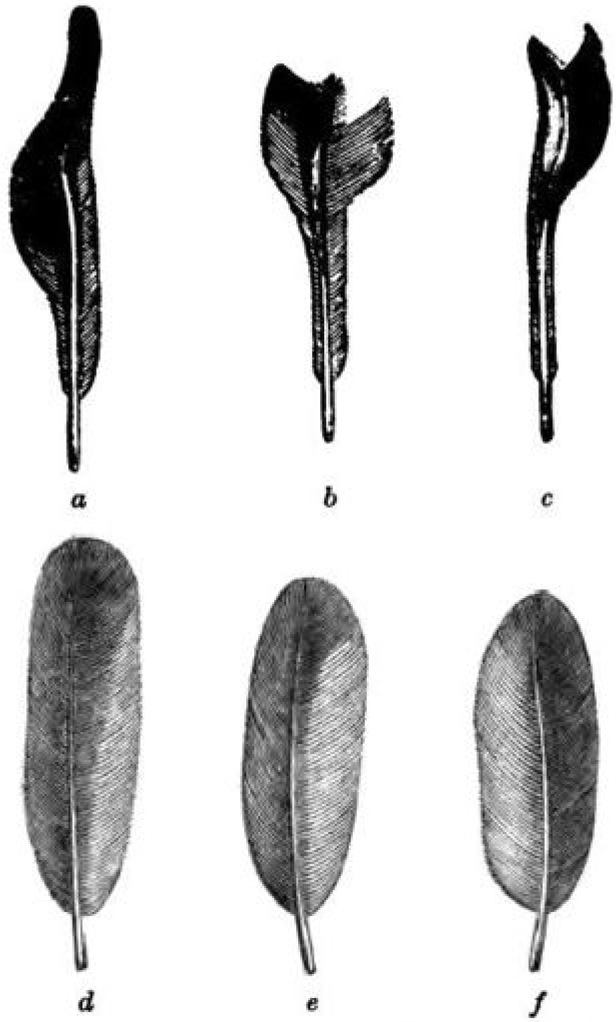
Chapter- 10

Bird Vocalization

A male Blackbird (*Turdus merula*) singing. Bogense havn, Funen, Denmark.

Bird vocalization includes both bird calls and bird songs. In non-technical use, bird songs are the bird sounds that are melodious to the human ear. In ornithology and birding, (relatively complex) songs are distinguished by function from (relatively simple) calls.

Definition



Secondary wing-feathers of *Pipra deliciosa* (from Mr. Sclater, in Proc. Zool. Soc. 1860). The three upper feathers, *a*, *b*, *c*, from the male; the three lower corresponding feathers, *d*, *e*, *f*, from the female.

a. and *d.* Fifth secondary wing-feather of male and female, upper surface. *b* and *e.* Sixth secondary, upper surface. *c* and *f.* Seventh secondary, lower surface.

Wing feathers of a male Club-winged Manakin, with the modifications noted noted by P L Sclater in 1860 and discussed by Charles Darwin in 1871

The distinction between songs and calls is based upon complexity, length, and context. Songs are longer and more complex and are associated with courtship and mating, while calls tend to serve such functions as alarms or keeping members of a flock in contact. Other authorities such as Howell and Webb (1995) make the distinction based on function, so that short vocalizations such as those of pigeons and even non-vocal sounds such as the drumming of woodpeckers and the "winnowing" of snipes' wings in display flight are considered songs. Still others require song to have syllabic diversity and temporal regularity akin to the repetitive and transformative patterns which define music.

It is generally agreed upon in birding and ornithology which sounds are songs and which are calls, and a good field guide will differentiate between the two.

Bird song is best developed in the order Passeriformes. Most song is emitted by male rather than female birds. Song is usually delivered from prominent perches although some species may sing when flying. Some groups are nearly voiceless, producing only percussive and rhythmic sounds, such as the storks, which clatter their bills. In some manakins (Pipridae), the males have evolved several mechanisms for mechanical sound production, including mechanisms for stridulation not unlike those found in some insects.

The production of sounds by mechanical means as opposed to the use of the syrinx has been termed variously *instrumental music* by Charles Darwin, *mechanical sounds* and more recently *sonation*. The term *sonate* has been defined as the act of producing non-vocal sounds that are intentionally modulated communicative signals, produced using non-syringeal structures such as the bill, wings, tail, feet and body feathers.

Anatomy

The avian vocal organ is called the syrinx; it is a bony structure at the bottom of the trachea (unlike the larynx at the top of the mammalian trachea). The syrinx and sometimes a surrounding air sac resonate to sound waves that are made by membranes past which the bird forces air. The bird controls the pitch by changing the tension on the membranes and controls both pitch and volume by changing the force of exhalation. It can control the two sides of the trachea independently, which is how some species can produce two notes at once.

Function

Scientists hypothesize that bird song has evolved through sexual selection, and experiments suggest that the quality of bird song may be a good indicator of fitness. Experiments also suggest that parasites and diseases may directly affect song characteristics such as song rate, which thereby act as reliable indicators of health. The song repertoire also appears to indicate fitness in some species. The ability of male birds to hold and advertise territories using song also demonstrates their fitness.

Communication through bird calls can be between individuals of the same species or even across species. Birds communicate alarm through vocalizations and movements that are specific to the threat, and bird alarms can be understood by other animal species, including other birds, in order to identify and protect against the specific threat. Mobbing calls are used to recruit individuals in an area where an owl or other predator may be present. These calls are characterized by wide frequency spectra, sharp onset and termination, and repetitiveness which are common across species and are believed to be helpful to other potential "mobbers" by being easy to locate. The alarm calls of most species, on the other hand, are characteristically high-pitched making the caller difficult to locate.

Individual birds may be sensitive enough to identify each other through their calls. Many birds that nest in colonies can locate their chicks using their calls. Calls are sometimes distinctive enough for individual identification even by human researchers in ecological studies.

Many birds engage in duet calls. In some cases the duets are so perfectly timed as to appear almost as one call. This kind of calling is termed antiphonal duetting. Such duetting is noted in a wide range of families including quails, bushshrikes, babblers such as the scimitar babblers, some owls and parrots. In territorial songbirds, birds are more likely to countersing when they have been aroused by simulated intrusion into their territory. This implies a role in intraspecies aggressive competition.

Some birds are excellent vocal mimics. In some tropical species, mimics such as the drongos may have a role in the formation of mixed-species foraging flocks. Vocal mimicry can include conspecifics, other species or even man-made sounds. Many hypotheses have been made on the functions of vocal mimicry including suggestions that they may be involved in sexual selection by acting as an indicator of fitness, help brood parasites, protect against predation but strong support is lacking for any function. Many birds, and especially those that nest in cavities, are known to produce a snake like hissing sound that may help deter predators at close range.

Some cave-dwelling species, including Oilbird and Swiftlets (*Collocalia* and *Aerodramus* spp.), use audible sound (with the majority of sonic location occurring between 2 and 5 kHz) to echolocate in the darkness of caves. The only bird known to make use of infrasound (at about 20 Hz) is the western capercaillie.

The hearing range of birds is from below 50 Hz (infrasound) to above 20 kHz (ultrasound) with maximum sensitivity between 1 and 5 kHz. The range of frequencies at which birds call in an environment varies with the quality of habitat and the ambient sounds. It has been suggested that narrow bandwidths, low frequencies, low-frequency modulations, and long elements and inter-element intervals should be found in habitats with complex vegetation structures (which would absorb and muffle sounds) while high frequencies, broad bandwidth, high-frequency modulations (trills), and short elements and inter-elements may be expected in habitats with herbaceous cover. It has been hypothesized that the available frequency range is partitioned and birds call so that overlap between different species in frequency and time is reduced. This idea has been termed the "acoustic niche". Birds sing louder and at a higher pitch in urban areas, where there is ambient low-frequency noise.

Bird Language

The language of the birds has long been a topic for anecdote and speculation. That calls have meanings that are interpreted by their listeners has been well demonstrated. Domestic chickens have distinctive alarm calls for aerial and ground predators, and they respond to these alarm calls appropriately. However a language has, in addition to words, structures and rules. Studies to demonstrate the existence of language have been difficult due to the range of possible interpretations. Research on parrots by Irene Pepperberg is claimed to demonstrate the innate ability for grammatical structures, including the existence of concepts such as nouns, adjectives and verbs. Studies on starling vocalizations have also suggested that they may have recursive structures.

The term "bird language" may also more informally refer to patterns in bird vocalizations that communicate information to other birds or other animals in general. Wilderness Awareness School groups bird vocalizations into 5 different classes, sometimes called "voices," each of which communicates different information. Companion calling is a short vocalization made between mates, parent and young, or members of a flock to maintain contact when out of visual range. Juvenile begging is a strident, loud vocalization often made by young to a parent when begging for food. Intraspecific aggression can consist of loud, alarmed-sounding vocalizations or of energetic song, and may be heard when members of the same species behave aggressively toward each other. Alarm may be heard when birds are startled, frightened, or terrified for their lives, and can take many forms. Mobbing is one example of alarm, while a high-pitched alarm call is another.

Of the 5 voices of the birds, four of them communicate the message that the bird feels safe. Birds that engage in song, companion calling, juvenile begging, and intraspecific aggression all display what Jon Young calls "baseline" behavior, or a relaxed state free of the fear of predation. Alarm communicates the presence of a predator, or an influence that the bird may see as predatory such as a human hiker. Alarms have distinct sounds and shapes, each of which is specific to the source of the disturbance. For example, ravens mobbing a hawk or owl in a tree will clump around the predator in a loose ball, calling and diving. If the ravens rise off the tree and fly higher, the predator was a hawk and has flown up to escape, as is typical of hawks. If the ravens drop out of the tree and fly low and away, the predator was an owl and has dropped low off its perch to escape, as is typical of owls.

Neurophysiology

The main brain areas involved in bird song are:

- Anterior forebrain pathway (vocal learning): composed of the lateral part of the magnocellular nucleus of anterior neostriatum (LMAN), which is a homologue to mammalian basal ganglia); Area X, which is part of the basal ganglia; and the Dorso-Lateral division of the Medial thalamus (DLM).
- Song production pathway: composed of the HVC (sometimes, inaccurately, called the Hyperstriatum Ventralis pars Caudalis); robust nucleus of the arcopallium (RA); and the tracheosyringeal part of the hypoglossal nucleus (nXIIts).

Both pathways show sexual dimorphism, with the male producing song most of the time. It has been noted that injecting testosterone in non-singing female birds can induce growth of the HVC and thus production of song.

Birdsong production is generally thought to start at the nucleus uvaeformis of the thalamus with signals emanating along a pathway that terminates at the syrinx. The pathway from the thalamus leads to the interfacial nucleus of the nidopallium to the HVC, and then to RA, the dorso-lateral division of the medial thalamus and to the tracheosyringeal nerve.

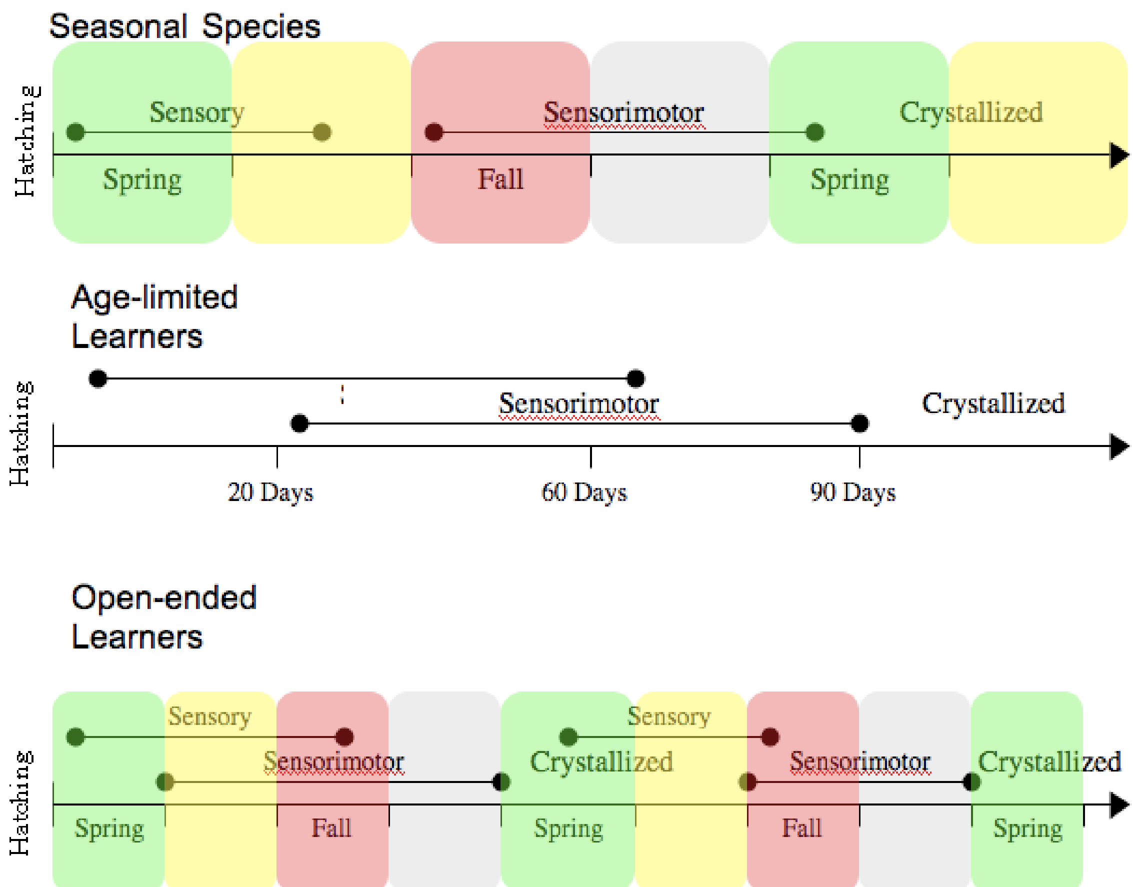
The gene FOXP2, defects of which affect both speech and comprehension of language in humans, becomes more active in the striatal region of songbirds during the time of song learning.

Recent research in birdsong learning has focused on the Ventral Tegmental Area (VTA), which sends a dopamine input to the para-olfactory lobe and Area X, LMAN and the ventrolateral medulla. Other researchers have explored the possibility that HVc is responsible for syllable production, while the robust nucleus of the arcopallium, the primary song output nucleus, may be responsible for syllable sequencing and production of notes within a syllable.

Learning

The songs of different species of birds vary, and are more or less characteristic of the species. In modern-day biology, bird song is typically analysed using acoustic spectroscopy. Species vary greatly in the complexity of their songs and in the number of distinct kinds of song they sing (up to 3000 in the Brown Thrasher); in some species, individuals vary in the same way. In a few species such as starlings and mockingbirds, songs imbed arbitrary elements learned in the individual's lifetime, a form of mimicry (though maybe better called "appropriation" [Ehrlich *et al.*], as the bird does not pass for another species). As early as 1773 it was established that birds learnt calls and cross-fostering experiments were able to force a Linnet *Acanthis cannabina* to learn the song of a skylark *Alauda arvensis*. In many species it appears that although the basic song is the same for all members of the species, young birds learn some details of their songs from their fathers, and these variations build up over generations to form dialects.

Birds learn songs early in life with sub-vocalizations that develop into renditions of adult songs. Zebra Finches, the most popular species for birdsong research, develop a version of a familiar adult's song after 20 or more days from hatch. By around 35 days, the chick will have learned the adult song. The early song is "plastic" or variable and it takes the young bird two or three months to perfect the "crystallized" song (which is less variable) of sexually mature birds.



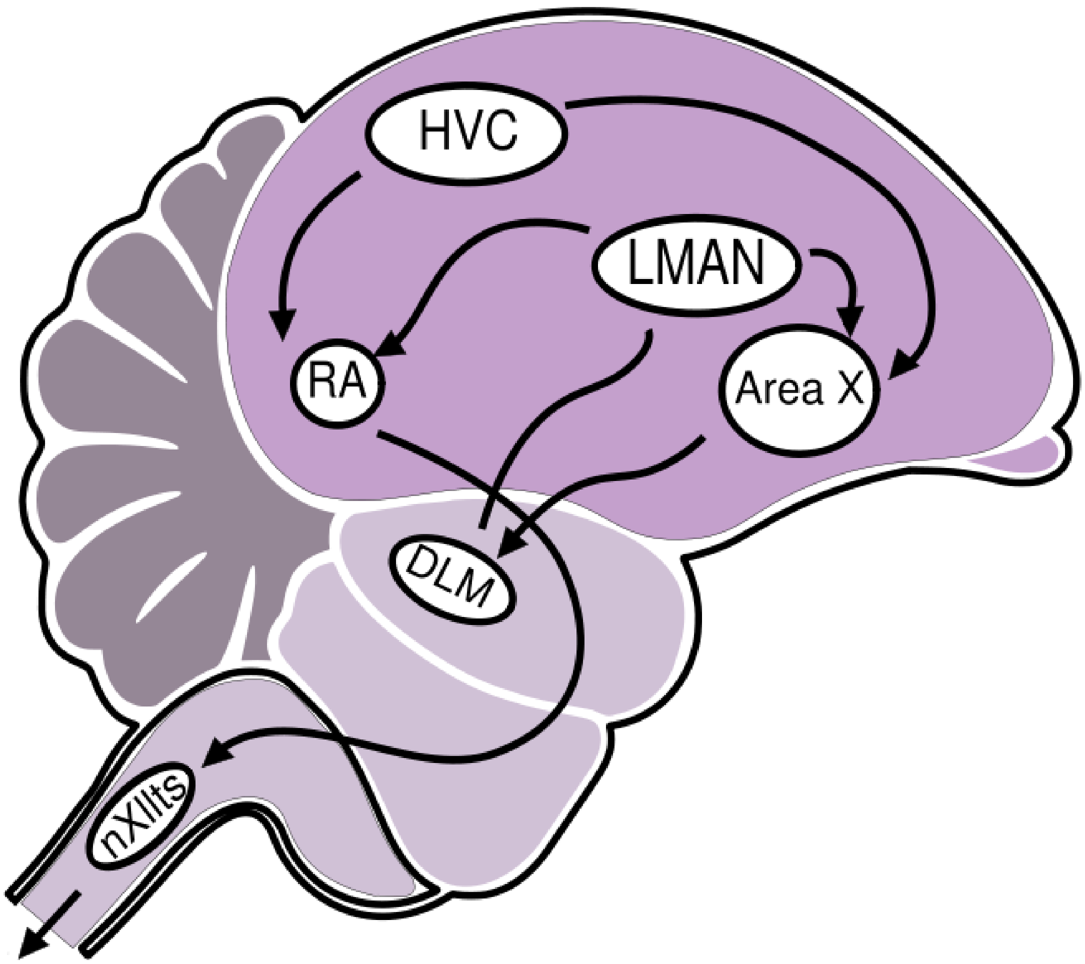
Timeline for song learning in different species. Diagram adapted from Brainard & Doupe, 2002.

Research indicates birds' acquisition of song is a form of motor learning that involves regions of the basal ganglia. Models of bird-song motor learning are sometimes used as models for how humans learn speech. In some species such as zebra finches, learning of song is limited to the first year; they are termed 'age-limited' or 'close-ended' learners. Other species such as the canaries can develop new songs even as sexually mature adults; these are termed 'open-ended' learners.

Researchers have hypothesized that learned songs allow the development of more complex songs through cultural interaction, thus allowing intraspecies dialects that help birds stay with their own kind within a species, and it allows birds to adapt their songs to different acoustic environments.

Auditory feedback in bird song learning

Early experiments by Thorpe in 1954 showed the importance of a bird being able to hear a tutor's song. When birds are raised in isolation, away from the influence of conspecific males, they still sing. While the song they produce resembles the song of a wild bird, it lacks the complexity and sounds distinctly different. The importance of the bird being able to hear himself sing in the sensorimotor period was later discovered by Konishi. Birds deafened before the song crystallization period went on to produce very different songs from the wild type. These findings lead scientists to believe there could be a specific part of the brain dedicated to this specific type of learning.



Song learning pathway in birds (Based on Nottebohm, 2005)

The main focus in the search for the neuronal aspect of bird song learning was guided by the song template hypothesis. This hypothesis is the idea that when a bird is young he memorizes the song of his tutor. Later, during the development phase as an adult, he matches his own trial vocalizations using auditory feedback to an acoustic template in the brain. Based on this information, he adjusts his song if needed. To find this "song template," experimenters lesioned certain parts of the brain and observed the effects.

- Lesioning the song production pathway (RA, xXII or HVc) in the brain creates serious effects on song production in all birds.

- Lesions parts of the anterior forebrain pathway, or vocal learning pathway, DLM and area X, result in deficits in learning in all birds.
- Lesioning LMAN, located in the anterior forebrain pathway in young birds disrupts song production.
- Lesioning LMAN on an adult bird shows no effect.
- Lesioning LMAN on an adult canary (an "open-ended learner" species, which can learn songs later in life) shows a progressive deterioration of song.

These results show that the area known as LMAN is the only brain area in the pathway that shows some plasticity and further studies have shown that this area of the brain responds best to the bird's own song. This neuroplasticity is vital for a bird being able to learn a song. The ability to make small adjustments based on auditory feedback is needed for the complexity of these beautiful songs. Just like any musician, birds need to practice and be able to evaluate what their song sounds like and what it's supposed to sound like in order to get it right.

To complete the picture on bird song learning, experimenters needed to discover the true plasticity of the brain. While deafening and creating auditory isolation were good techniques for discovering basic characteristics about the brain, a reversible procedure was needed to investigate further. The solution was found in disruption of the auditory feedback, or what a bird hears. A computer is able to capture the song of a singing bird and play back portions of its song, or selectively play back a certain syllable while the bird is singing. The computer is basically playing the age old trick of repeating whatever the bird sings, the "stop copying me" game. This creates such a disruption that an adult bird will start to decrystallize its song, which includes a loss of spectral and temporal rigidity characteristic of adult song. It reverts back to the song it started singing with, before any learning took place. Furthermore, when the feedback was stopped, the birds slowly recovered their original song, something that was unheard of. These results show that there is a fair amount of plasticity retained in the brain, even for close-ended learners. This new found plasticity in adult birds and the results on the plasticity of LMAN (shown above) combine into a model for bird song learning (diagram coming soon).

Mirror neurons and vocal learning

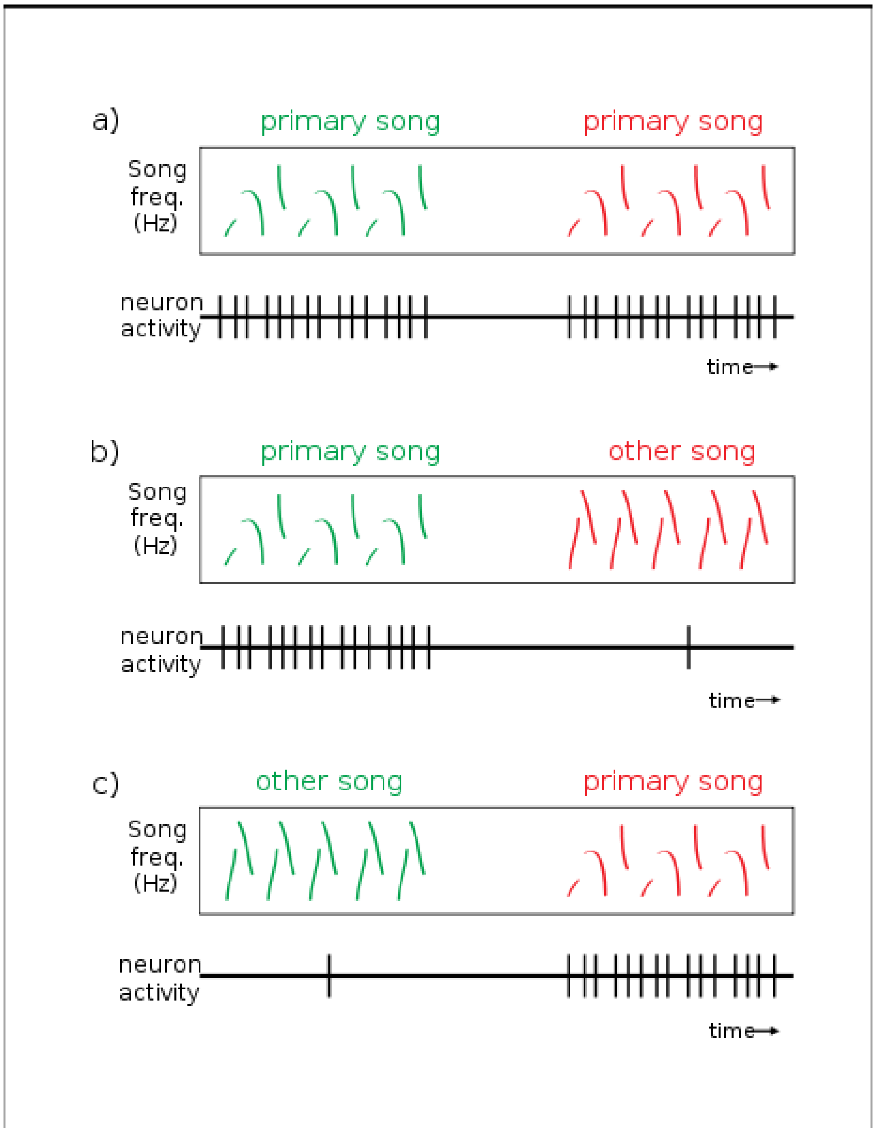
A mirror neuron is a neuron that discharges both when an individual performs an action, and when he perceives that same action being performed by another. These neurons were first discovered in macaque monkeys, but recent research suggests that mirror neuron systems may be present in other animals including humans.

Mirror neurons have the following characteristics:

- They are located the premotor cortex
- They exhibit both sensory and motor properties

- They are action-specific – mirror neurons are only active when an individual is performing or observing a certain type of action (e.g.: grasping an object).

Because mirror neurons exhibit both sensory and motor activity, some researchers have suggested that mirror neurons may serve to map sensory experience onto motor structures. This has implications for birdsong learning– many birds rely on auditory feedback to acquire and maintain their songs. Mirror neurons may be mediating this comparison of what the bird hears and what he produces.



Song selectivity in HVCx neurons: neuron activity in response to calls heard (green) and calls produced (red). **a.** Neurons fire when the primary song type is either heard or sung. **b,c.** Neurons do not fire in response to the other song type, regardless of whether it is heard or sung. Sketch based on figure from Prather et al. (2008)

In search of these auditory-motor neurons, Jonathan Prather and other researchers at Duke University recorded the activity of single neurons in the HVCs of swamp sparrows. They discovered that the neurons that project from the HVC to Area X (HVC_X neurons) are highly responsive when the bird is hearing a playback of his own song. These neurons also fire in similar patterns when the bird is singing that same song. Swamp sparrows employ 3-5 different song types, and the neural activity differs depending on which song is heard or sung. The HVC_X neurons only fire in response to the presentation (or singing) of one of the songs, the primary song type. They are also temporally selective, firing at a precise phase in the song syllable.

Because the timing of the neural response is identical regardless of whether the bird was listening or singing, how can we be sure that the bird isn't just hearing himself? Prather et al. found that during the short period of time before and after the bird sings, his HVC_X neurons become insensitive to auditory input. In other words, the bird becomes "deaf" to his own song. This suggests that these neurons are producing a corollary discharge, which would allow for direct comparison of motor output and auditory input. This may be the mechanism underlying learning via auditory feedback.

Overall, the HVC_X auditory-motor neurons in swamp sparrows are very similar to the visual-motor mirror neurons discovered in primates. Like mirror neurons, the HVC_X neurons:

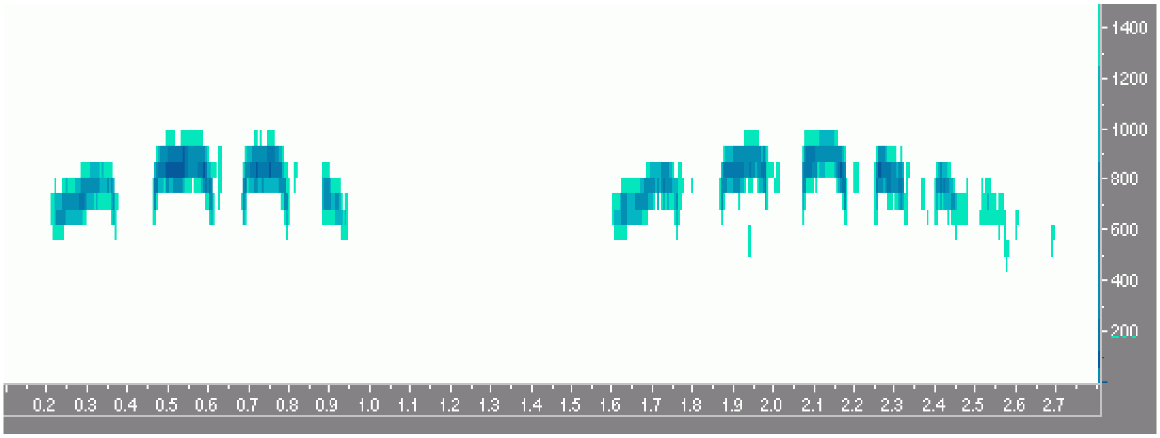
- Are located in a premotor brain area
- Exhibit both sensory and motor properties
- Are action-specific – a response is only triggered by the 'primary song type'

The function of the mirror neuron system is still unclear. Some scientists speculate that mirror neurons may play a role in understanding the actions of others, imitation, theory of mind and language acquisition, though there is currently insufficient neurophysiological evidence in support of these theories. Specifically regarding birds, it is possible that the mirror neuron system serves as a general mechanism underlying vocal learning, but further research is needed. In addition to the implications for song learning, the mirror neuron system could also play a role in territorial behaviors such as song-type matching and countersinging.

Identification and systematics

The specificity of bird calls has been used extensively for species identification. The calls of birds have been described using words or nonsense syllables, or line diagrams. Common terms in English include words such as *quack*, *chirp* and *chirrup*. These are subject to imagination and vary greatly; a well-known example is the White-throated Sparrow's song, given in Canada as *O sweet Canada Canada Canada* and in New England as *Old Sam Peabody Peabody Peabody* (also *Where are you Frederick Frederick Frederick?*). In addition to nonsense words, grammatically correct phrases have been constructed as likenesses of the vocalizations of birds. For example, the Barred

Owl produces a motif which some bird guides describe as *Who cooks for you? Who cooks for you all?* with the emphasis placed on *you*.



Sonogram of the call of a Laughing Dove.

The use of spectrograms to visualize bird song was first introduced by W. H. Thorpe. These visual representations are also called sonograms or sonagrams. Some recent field guides for birds use sonograms to document the calls and songs of birds. The sonogram is objective, unlike descriptive phrases, but proper interpretation requires experience. Sonograms can also be roughly converted back into sound.

Bird song is an integral part of bird courtship and is a pre-zygotic isolation mechanism involved in the process of speciation. Many allopatric sub-species show differences in calls. These differences are sometimes minute, often detectable only in the sonograms. Song differences in addition to other taxonomic attributes have been used in the identification of new species. The use of calls has led to proposals for splitting of species complexes such as those of the *Mirafra* Bushlarks.

Bird song and music

Some musicologists believe that birdsong has had a large influence on the development of music. Although the extent of this influence is impossible to gauge, it is sometimes easy to see some of the specific ways composers have integrated birdsong with music.

There seem to be three general ways musicians or composers can be affected by birdsong: they can be influenced or inspired (consciously or unconsciously) by birdsong, they can include intentional imitations of bird song in a composition, or they can incorporate recordings of birds into their works.

One early example of a composition that imitates birdsong is Janequin's "Le Chant Des Oiseaux", written in the 16th century. Other composers who have quoted birds or have used birdsong as a compositional springboard include Vivaldi (*Spring* from the *Four Seasons*)), Biber (*Sonata Representativa*), Beethoven (*Sixth Symphony*), Wagner

(*Siegfried*) and the jazz musicians Paul Winter (*Flyway*) and Jeff Silverbush (*Grandma Mickey*).

The twentieth-century French composer Olivier Messiaen composed with birdsong extensively. His Catalogue d'Oiseaux is a seven-book set of solo piano pieces based upon birdsong. His orchestral piece *Réveil des Oiseaux* is composed almost entirely of birdsong. Many of his other compositions, including *Quatuor pour la fin du temps*, similarly integrate birdsong.

The Italian composer Ottorino Respighi, with his *The Pines of Rome* (1923–1924), may have been the first to compose a piece of music that calls for pre-recorded birdsong. A few years later, Respighi wrote *Gli Uccelli* ("The birds"), based on Baroque pieces imitating birds.

The Finnish composer Einojuhani Rautavaara in 1972 wrote an orchestral piece of music called *Cantus Arcticus* (Opus 61, dubbed *Concerto for Birds and Orchestra*) making extensive use of pre-recorded birdsongs from Arctic regions, such as migrating swans.

The American jazz musician Eric Dolphy sometimes listened to birds while he practiced flute. He claimed to have incorporated bird song into some of his improvisational music.

In the psychedelic era of the 1960s and 1970s, many rock bands included sound effects in their recordings. Birds were a popular choice. The English band Pink Floyd included bird sound effects in many of the songs from their 1969 albums *Soundtrack from the Film More* and *Ummagumma* (for example, Grantchester Meadows). Similarly, the English singer Kate Bush incorporated bird sound effects into much of the music on her 2005 album, Aerial.

The Music hall artist Ronnie Ronalde has gained notoriety for his whistling imitations of birds and for integrating birdsong with human song. His songs 'In A Monastery Garden' and 'If I Were A Blackbird' include imitations of the blackbird, his "signature bird."

The French composer François-Bernard Mâche has been credited with the creation of zoomusicology, the study of the music of animals. His essay *Musique, mythe, nature, ou les Dauphins d'Arion* (1983) includes a study of "ornitho-musicology", in which he speaks of "animal musics" and a longing to connect with nature.

The German DJ, techno music producer and naturalist Dominik Eulberg is an avid bird watcher, and several tracks by him prominently feature sampled bird sounds and even are titled after his favourite specimens.

The productions of The Jewelled Antler Collective often use field recordings featuring birdsong.

In 2007, The CT Collective issed two free albums devoted to music made using bird songs (one with human interaction, one without). The project was co-ordinated by looping musician Nick Robinson

Bird song and poetry

Bird song is a popular subject in poetry. Famous poems inspired by bird song include Percy Bysshe Shelley's To a Skylark ("Hail to thee, blithe Spirit!/Bird thou never wert") and Gerard Manley Hopkins' Sea and Skylark. Birdsongs and their relations to Middle-earth inhabitants are a common motif in J. R. R. Tolkien's literary work. The Grateful Dead performed a song called "Bird Song" that Jerry Garcia wrote and dedicated to Janis Joplin.

Chapter- 11

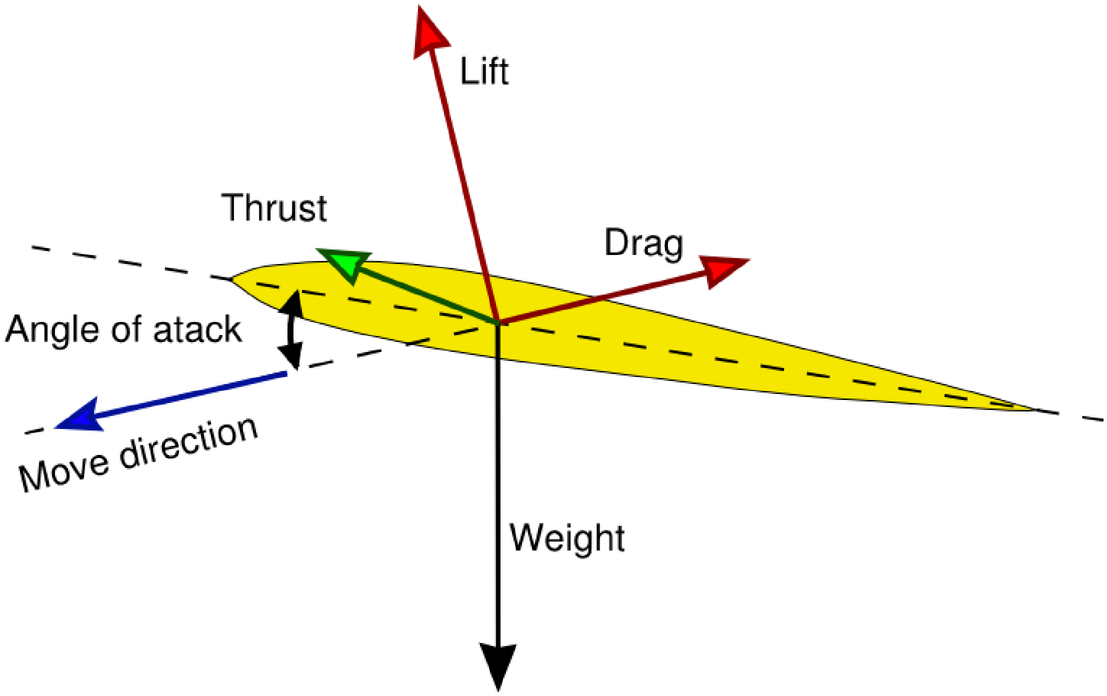
Bird Flight

A magpie-goose taking off

Flight is the main mode of locomotion used by most of the world's bird species. Flight assists birds while feeding, breeding and avoiding predators.

This chapter discusses the mechanics of **bird flight**, with emphasis on the varied forms of bird's wings. The specifics of hovering, take-off and landing are also examined. Additional adaptations of bird's bodies relating to their flying ability are covered. Finally, theories on the evolution of bird flight.

Basic mechanics of bird flight



Forces acting on a wing. The lift force has both a forward and a vertical component.

Lift

The fundamentals of bird flight are similar to those of aircraft. Lift force is produced by the action of air flow on the wing, which is an airfoil. The lift force occurs because the air has a lower pressure just above the wing and higher pressure below.

Gliding

When gliding, both birds and gliders obtain both a vertical and a forward force from their wings. This is possible because the lift force is generated at right angles to the air flow, which in gliding flight comes from slightly below the horizontal (because the bird is descending). The lift force, therefore, has a forward component that counteracts drag.

A flock of domestic pigeons each in a different phase of its flap

Flapping

When a bird flaps, as opposed to gliding, its wings continue to develop lift as before, but the lift is rotated forward to provide thrust, which counteracts drag and increases its speed, which has the effect of also increasing lift to counteract its weight, allowing it to maintain height or to climb. Flapping involves two stages: the down-stroke, which provides the majority of the thrust, and the up-stroke, which can also (depending on the bird's wings) provide some thrust. At each up-stroke the wing is slightly folded inwards to reduce upward resistance. Birds change the angle of attack between the up-stroke and the down-stroke of their wings. During the down-stroke the angle of attack is increased, and is decreased during the up-stroke.

Drag

Apart from its weight, there are three major drag forces that impede a bird's aerial flight: frictional drag (caused by the friction of air and body surfaces), form drag (due to frontal area of the bird, also known as pressure drag), and lift-induced drag (caused by the wingtip vortices). These forces are reduced by streamlining the bird's body and wings.

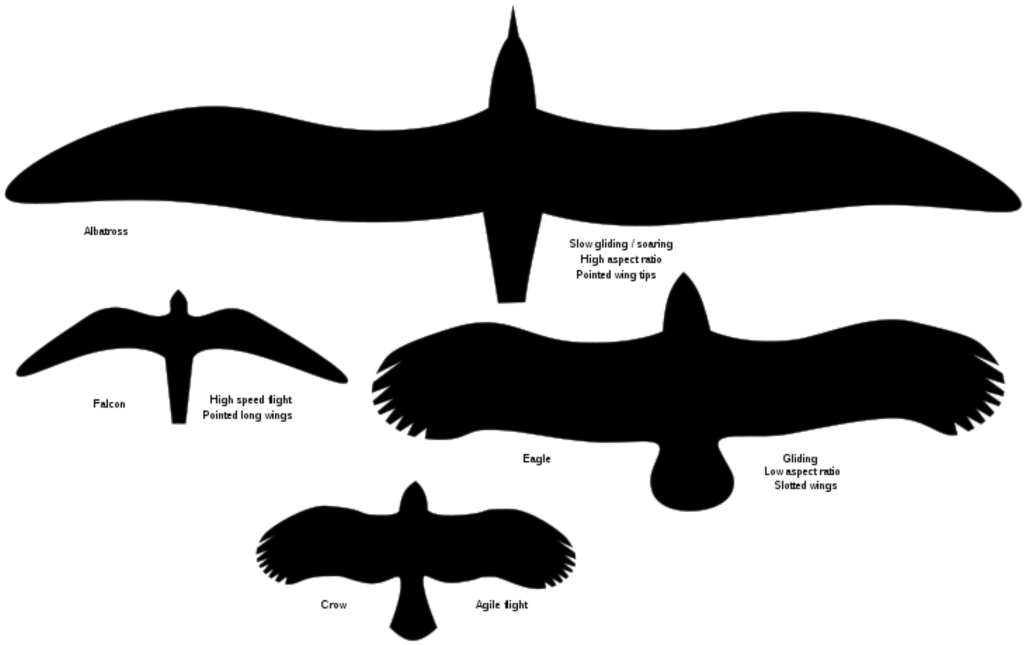
Wing

A kea in flight

The bird's forelimbs, the wings, are the key to bird flight. Each wing has a central vane to hit the wind, composed of three limb bones, the humerus, ulna and radius. The hand, or manus, which ancestrally was composed of five digits, is reduced to three digits (digit II, III and IV or I, II, III depending on the scheme followed), which serves as an anchor for the primaries, one of two groups of flight feathers responsible for the wing's airfoil shape. The other set of flight feathers, behind the carpal joint on the ulna, are called the secondaries. The remaining feathers on the wing are known as coverts, of which there are three sets. The wing sometimes has vestigial claws. In most species these are lost by the time the bird is adult (such as the highly visible ones used for active climbing by Hoatzin chicks), but claws are retained into adulthood by the Secretary Bird, screamers, finfoots, ostriches, several swifts and numerous others, as a local trait, in a few specimens. The claws of the Jurassic theropod-like Archaeopteryx are quite similar to those of the Hoatzin nestlings.

Albatrosses have locking mechanism in the wing joints that reduce the strain on the muscles during soaring flight.

Wing shape and flight



Wing shapes

The shape of the wing is an important factor in determining the types of flight of which the bird is capable. Different shapes correspond to different trade-offs between beneficial characteristics, such as speed, low energy use, and maneuverability. The planform of the wing (the shape of the wing as seen from below) can be described in terms of two parameters, aspect ratio and wing loading. Aspect ratio is the ratio of wingspan to the mean of its chord (or the square of the wingspan divided by wing area). Wing loading is the ratio of weight to wing area.

Most kinds of bird wing can be grouped into four types, with some falling between two of these types. These types of wings are elliptical wings, high speed wings, high aspect ratio wings and soaring wings with slots.

Elliptical wings

Elliptical wings are short and rounded, having a low aspect ratio, allowing for tight maneuvering in confined spaces such as might be found in dense vegetation. As such they are common in forest raptors (such as *Accipiter* hawks), and many passerines, particularly non-migratory ones (migratory species have longer wings). They are also common in species that use a rapid take off to evade predators, such as pheasants and partridges.

High speed wings

High speed wings are short, pointed wings that when combined with a heavy wing loading and rapid wingbeats provide an energetically expensive high speed. This type of flight is used by the bird with the fastest wing speed, the peregrine falcon, as well as by most of the ducks. The same wing shape is used by the auks for a different purpose; auks use their wings to "fly" underwater. The Peregrine Falcon has the highest recorded dive speed of 175 mph (282 km/h). The fastest straight, powered flight is the Spine-tailed Swift at 105 mph (170 km/h).

A Roseate Tern uses its low wing loading and high aspect ratio to achieve low speed flight

High aspect ratio wings

High aspect ratio wings, which usually have low wing loading and are far longer than they are wide, are used for slower flight, almost hovering (as used by kestrels, terns and nightjars) or alternatively by birds that specialize in soaring and gliding flight, particularly that used by seabirds, dynamic soaring, which use different wind speeds at different heights (wind shear) above the waves in the ocean to provide lift. Low speed flight is important for birds that plunge dive for fish.

Soaring wings with deep slots

These are the wings favored by the larger species of inland birds, such as eagles, vultures, pelicans, and storks. The slots at the end of the wings, between the primaries, reduce the induced drag and wingtip vortices by "capturing" the energy in air flowing from the lower to upper wing surface at the tips, whilst the shorter size of the wings aids in takeoff (high aspect ratio wings require a long taxi in order to get airborne).

Hovering

Hovering is used by several species of birds (and specialized in by one family). True hovering, which is generating lift through flapping alone rather than as a product of the bird's passage through the air, demands a lot of energy. This means that it is confined to smaller birds; the largest bird able to truly hover is the pied kingfisher, although larger birds can hover for short periods of time. Larger birds that hover for prolonged periods do so by flying into a headwind, allowing them to remain stationary relative to the ground (or water). Kestrels, terns and even hawks use this windhovering.

The ruby-throated Hummingbird can beat its wings 52 times a second

Most birds that hover have high aspect ratio wings that are suited to low speed flying. One major exception to this are the hummingbirds, which are the most accomplished hoverers of all the birds. Hummingbird flight is different from other bird flight in that the wing is extended throughout the whole stroke, the stroke being a symmetrical figure of eight, with the wing producing lift on both the up- and down-stroke. Some hummingbirds can beat their wings 52 times a second, though others do so less frequently.

Take-off and landing

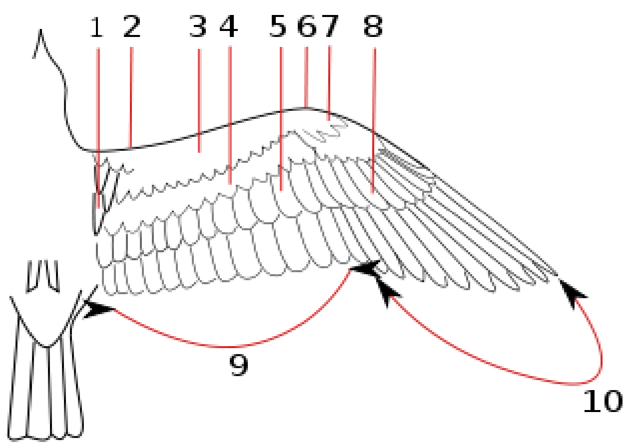
A male bufflehead runs atop the water while taking off

Take-off is one of the most energetically demanding aspects of flight, as the bird needs to generate enough airflow across the wing to create lift. With small birds a jump up will suffice, while for larger birds this is not possible. In this situation, birds need to take a run up in order to generate the airflow to take off. Large birds take off by facing into the wind, or, if they can, by perching on a branch or cliff so that all they need to do is drop off into the air.

Landing is also a problem for large birds with high wing loadings. This problem is dealt with in some species by aiming for a point below the intended landing area (such as a nest on a cliff) then pulling up beforehand. If timed correctly, the airspeed once the target is reached is virtually nil. Landing on water is simpler, and the larger waterfowl species prefer to do so whenever possible, landing into wind and using their feet as skids. In order to lose height rapidly prior to landing, some large birds such as geese indulge in a rapid alternating series of sideslips in a maneuver termed as *whiffling*.

Mute Swan *Cygnus olor*

Adaptations for flight



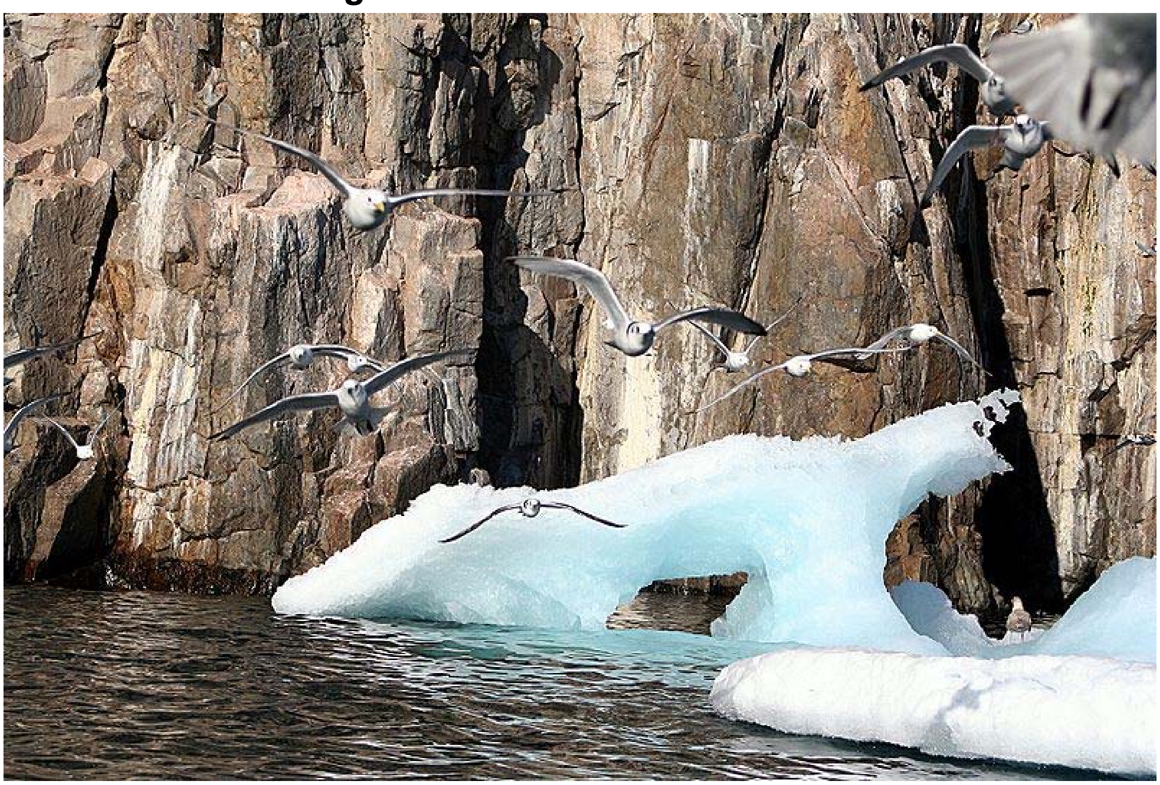
1 Axillaries; 2 Margin (Marginal underwing coverts); 3 Lesser underwing coverts; 4 Median underwing coverts (Secondary coverts); 5 Greater underwing coverts (Secondary

coverts); 6 Carpal joint; 7 Lesser underwing primary coverts; 8 Greater undering primary coverts; 9 Secondaries; 10 Primaries

The most obvious adaptation to flight is the wing, but because flight is so energetically demanding birds have evolved several other adaptations to improve efficiency when flying. Birds' bodies are streamlined to help overcome air-resistance. Also, the bird skeleton is hollow to reduce weight, and many unnecessary bones have been lost (such as the bony tail of the early bird *Archaeopteryx*), along with the toothed jaw of early birds, which has been replaced with a lightweight beak. The skeleton's breastbone has also adapted into a large keel, suitable for the attachment of large, powerful flight muscles. The vanes of the feathers have hooklets called barbules that zip them together, giving the feathers the strength needed to hold the airfoil (these are often lost in flightless birds).

The large amounts of energy required for flight have led to the evolution of a unidirectional pulmonary system to provide the large quantities of oxygen required for their high respiratory rates. This high metabolic rate produces large quantities of radicals in the cells that can damage DNA and lead to tumours. Birds, however, do not suffer from an otherwise expected shortened lifespan as their cells have evolved a more efficient antioxidant system than those found in other animals.

Evolution of bird flight



Marine birds fly at Cape Hay in the High Arctic

Most paleontologists agree that birds evolved from small theropod dinosaurs, but the origin of bird flight is one of the oldest and most hotly contested debates in paleontology. The four main hypotheses are: "from the trees down", that birds' ancestors first glided down from trees and then acquired other modifications that enabled true powered flight; "from the ground up", that birds' ancestors were small, fast predatory dinosaurs in which feathers developed for other reasons and then evolved further to provide first lift and then true powered flight; and "wing-assisted incline running" (WAIR), a version of "from the ground up" in which birds' wings originated from forelimb modifications that provided *downforce*, enabling the proto-birds to run up extremely steep slopes such as the trunks of trees; and "Pouncing Proavis", which posits that flight evolved by modification from arboreal ambush tactics.

There has also been debate about whether the earliest known bird, *Archaeopteryx*, could fly. It appears that *Archaeopteryx* had the brain structures and inner-ear balance sensors that birds use to control their flight. *Archaeopteryx* also had a wing feather arrangement like that of modern birds and similarly asymmetrical flight feathers on its wings and tail. But *Archaeopteryx* lacked the shoulder mechanism by which modern birds' wings produce swift, powerful upstrokes; this may mean that it and other early birds were incapable of flapping flight and could only glide. The presence of most fossils in marine sediments in habitats devoid of vegetation has led to the hypothesis that they may have used their wings as aids to run across the water surface in the manner of the basilisk lizards.

From the trees down

This was the earliest hypothesis, encouraged by the examples of gliding vertebrates such as flying squirrels. It suggests that proto-birds like *Archaeopteryx* used their claws to clamber up trees and glided off from the tops.

Some recent research undermines the "trees down" hypothesis by suggesting that the earliest birds and their immediate ancestors did not climb trees. Modern birds that forage in trees have much more curved toe-claws than those that forage on the ground. The toe-claws of Mesozoic birds and of closely-related non-avian theropod dinosaurs are like those of modern ground-foraging birds.

From the ground up

Feathers are very common in coelurosaurid dinosaurs (including the early tyrannosauroid Dilong). Modern birds are classified as coelurosaurs by nearly all palaeontologists, though not by a few ornithologists. The original functions of feathers may have included thermal insulation and competitive displays. The most common version of the "from the ground up" hypothesis argues that bird's ancestors were small ground-running predators (rather like roadrunners) that used their forelimbs for balance while pursuing prey and that the forelimbs and feathers later evolved in ways that provided gliding and then powered flight. Another "ground upwards" theory argues the evolution of flight was initially driven by competitive displays and fighting: displays required longer feathers and longer, stronger forelimbs; many modern birds use their wings as weapons, and downward blows have a similar action to that of flapping flight. Many of the *Archaeopteryx* fossils come from marine sediments and it has been suggested that wings may have helped the birds run over water in the manner of the *Jesus Christ Lizard* (Common basilisk).

Most recent attacks on the "from the ground up" hypothesis attempt to refute its assumption that birds are modified coelurosaurid dinosaurs. The strongest attacks are based on embryological analyses, which conclude that birds' wings are formed from digits 2, 3 and 4 (corresponding to the index, middle and ring fingers in humans; the first of a bird's 3 digits forms the alula, which they use to avoid stalling on low-speed flight, for example when landing); but the hands of coelurosaurs are formed by digits 1, 2 and 3 (thumb and first 2 fingers in humans). However these embryological analyses were immediately challenged on the embryological grounds that the "hand" often develops differently in clades that have lost some digits in the course of their evolution, and therefore bird's hands do develop from digits 1, 2 and 3.

Wing-assisted incline running

The WAIR hypothesis was prompted by observation of young chukar chicks, and proposes that wings developed their aerodynamic functions as a result of the need to run quickly up very steep slopes such as tree trunks, for example to escape from predators. Note that in this scenario birds need *downforce* to give their feet increased grip. But early birds, including *Archaeopteryx*, lacked the shoulder mechanism by which modern birds' wings produce swift, powerful upstrokes; since the downforce on which WAIR depends is generated by upstrokes, it seems that early birds were incapable of WAIR.

Pouncing Proavis model

This theory was first proposed by Garner, Taylor, and Thomas in 1999:

We propose that birds evolved from predators that specialized in ambush from elevated sites, using their raptorial hindlimbs in a leaping attack. Drag–based, and later lift-based, mechanisms evolved under selection for improved control of body position and locomotion during the aerial part of the attack. Selection for enhanced lift-based control led to improved lift coefficients, incidentally turning a pounce into a swoop as lift production increased. Selection for greater swooping range would finally lead to the origin of true flight.

The authors believed that this theory had four main virtues:

- It predicts the observed sequence of character acquisition in avian evolution.
- It predicts an Archaeopteryx-like animal, with a skeleton more or less identical to terrestrial theropods, with few adaptations to flapping, but very advanced aerodynamic asymmetrical feathers.

- It explains that primitive pouncers (perhaps like Microraptor) could coexist with more advanced fliers (like Confuciusornis or Sapeornis) since they did not compete for flying niches.
- It explains that the evolution of elongated rachis-bearing feathers began with simple forms that produced a benefit by increasing drag. Later, more refined feather shapes could begin to also provide lift.

Uses and loss of flight in modern birds

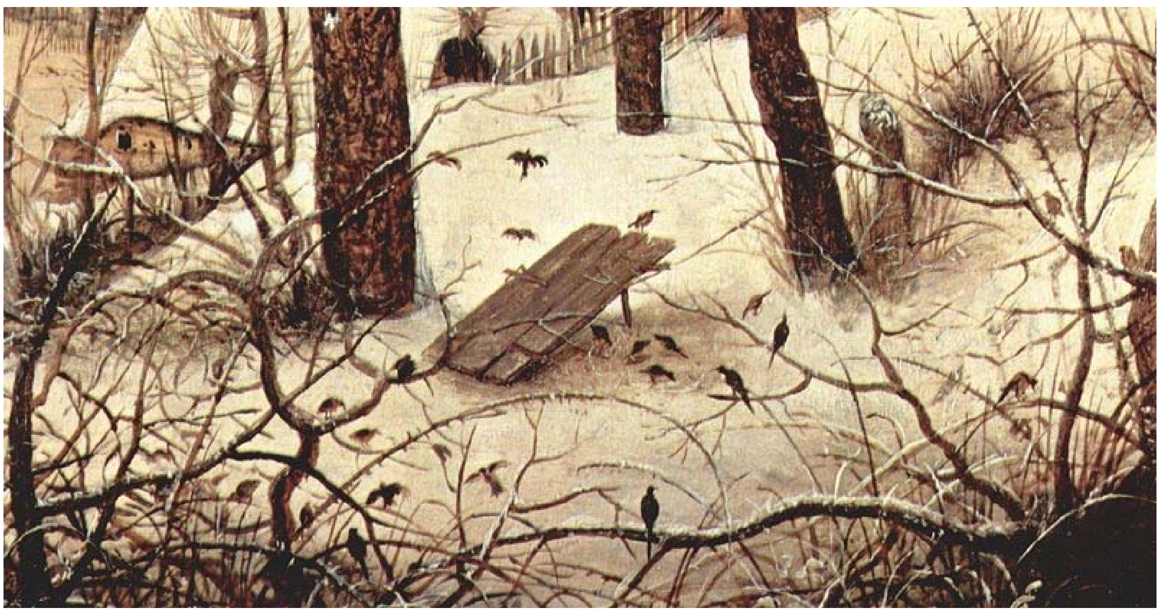
Birds use flight to obtain prey on the wing, for foraging, to commute to feeding grounds, and to migrate between the seasons. It is also used by some species to display during the breeding season and to reach safe isolated places for nesting.

Flight is more energetically expensive in larger birds, and many of the largest species fly by soaring and gliding (without flapping their wings) as much as possible. Many physiological adaptations have evolved that make flight more efficient.

Birds that settle on isolated oceanic islands that lack ground-based predators often lose the ability to fly. This illustrates both flight's importance in avoiding predators and its extreme demand for energy.

Chapter- 12

Bird Trapping



Painting of a lethal "deadfall" bird trap by Pieter Bruegel the Elder in 1565

Bird trapping techniques to capture wild birds include a wide range of techniques that have their origins in the hunting of birds for food. While hunting for food does not require the birds to be caught alive, some trapping techniques are used to capture birds without harming them particularly for research in ornithology. Birds may also be trapped for their display in captivity in zoological gardens or for keeping as a pet. Bird trapping was formerly unregulated, but to protect bird populations many countries saw a need to enact specific laws and regulations.

Trapping techniques used for research

Almost all traps make involve the use of food, water or a decoys to attract birds within range and a mechanism for restricting the movement, injuring or killing birds that come into range. Food, water, decoy birds and call playback may be used to bring birds to the trap. The use of chemical sprays on crops or food can have more widespread effects and are not usually included in trapping techniques although there are some capture techniques that make use of bait with stupefying agents. The mechanism can be physical and non-lethal like a noose that tightens around the leg or lethal like in deadfall traps. Lethal techniques have been used for the control of birds considered as pests or can be used in the capture of birds for food. Traps can vary in their design to capture individual birds or large flocks and are adapted according to the habitat and behaviour of the birds. Trapping is regulated in most countries and need to be operated by trained research personnel and failure to follow precautions can lead to injury or death of birds.

Clap traps

Clap traps are spring loaded frames with netting that are set up in two parts that come together rapidly when triggered by birds or manually controlled to enclose birds. They are usually used for ground birds but some variants are used in shallow water for the capture of waterfowl. Clap traps may be placed at a location habitually used by birds or can include luring devices.

Funnel traps

Funnel traps have a narrow entrance into which birds may be lured or driven and the entrance typically leads to larger holding pen or corral (which also gives them the name of corral trap). Funnel traps can be very large and a particularly well-known large scale form was devised in the German bird observatory at Heligoland and are termed as a Heligoland trap.

Cannon nets

Flocking birds are sometimes trapped using a large net which is thrown using a series of synchronized cannons or rockets that shoot a weight that drags a net behind it over the entire flock. These nets are also called rocket nets or boom nets. Capturing entire flocks can be an important in studies where large numbers of birds need to be examined (such as when monitoring for viruses) or when the birds are gregarious and social. These techniques are used especially in open habitats and are particularly suited for waders and waterbirds. After examination, ringing or other operations, the captured birds are usually released together rather than individually.

Mist nets

Mist nets are fine nets that are suitable for capturing birds in woodlands. The fine net is strung across trees so as to lie in the flight path of a bird. A bird flies into the nearly invisible net and falls to a fold at the bottom of the net where it usually gets entangled. These nets are used especially in bird ringing and are typically never left unsupervised. A bird that falls is quickly removed to avoid injury to the bird and to prevent them from falling prey to predators.

Noose traps

Birds that walk on the ground can be captured using an array of mono-filament nooses. These are usually placed along favoured feeding, roosting or nest sites. Some raptors are trapped using live-bait and nooses on the cage holding the bait. This trap, also known as a *bal-chatri*, has also been adapted to capture other birds such as shrikes. A "noose carpet" is another variant that consists of a number of tiny nooses on a mat.

Birdlime

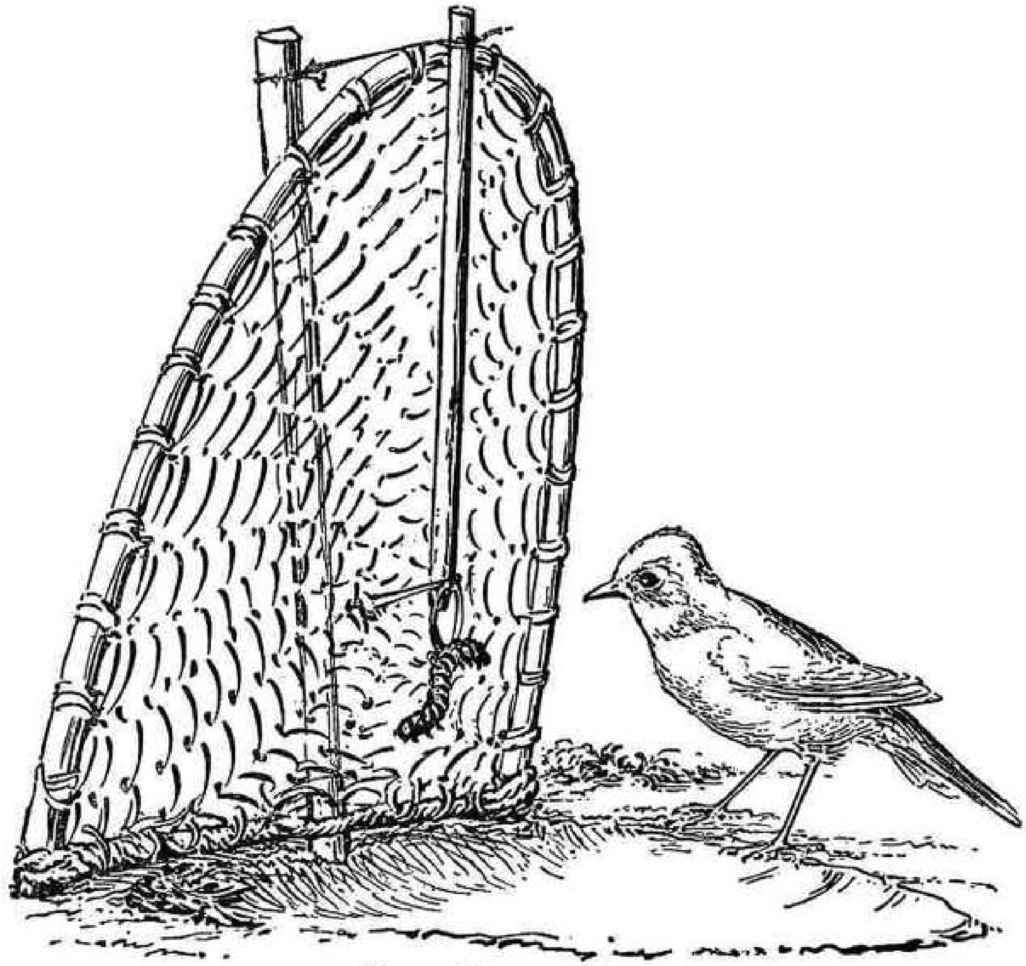
The muscles of perching birds allow the toes to pull inwards with some force but there are no strong muscles to open them up. The application of sticky latex, "birdlime", often obtained from a local tree to favourite perches is used in many parts of the world to capture small birds. Other variations include the use of a long stick daubed with birdlime that is manually placed over the bird to cause its wings to get stuck. The sale and use of birdlime is illegal in many jurisdictions but its use was widespread in older times.

Spot-light trapping

Netting larks at night with a lantern

Some birds such as partridges and pheasants can be caught in the night by stunning them with bright light beams. Before the 19th Century, lanterns were used for hunting larks at night in Spain, Italy and England.

Other methods used in control and hunting



Tunisian Nightingale Trap.

A baited trap

A number of lethal techniques have been described for the killing of birds. Dead-fall traps, consisting of heavy slabs or branches, that fall onto the targets when they trigger it from below have been described from early times. A painting of such a trap for killing crows was made by Pieter Bruegel the Elder in 1565. Birds are particularly vulnerable at their nest and a variety of methods to capture nesting birds exist around the world. In 2005, after a 100-year long prohibition, the French government permitted the reintroduction of the use of stone traps ("tendelles") in the Départements Lozère and Aveyron. Around the Meditarranean birds are caught in France, Italy, Spain, Greece, Cyrus, Malta and other countries by traps specifically during the migratory seasons when birds travel between Europe and Africa and back. In many countries trapping of wild birds is illegal and thus represents poaching. Cyprus is a stepping stone in the eastern European-African flyway. Although illegal for decades bird trapping is a black market enterprise with a profitable sale of birds to restaurants that cater to their patrons serving ambelopoulia. The spring 2010 led to the killing of over a quarter million of birds in Cyprus. Some birds with weak flight can be captured by chasing them. In India waterfowl were once captured by hunters who walked underwater with an earthen pot over their head. By walking up to floating ducks they could grab the legs of the duck. Empty pots were floated for a few days to make the birds accustomed to them.

Laws

Capturing gannets with a noose

Most countries have laws prohibiting the use of traps for capturing birds. Professional bird trapping may be regulated by licenses and researchers requiring to trap bird will usually need to obtain permissions. Hunting to some extent may however be allowed and some birds may be exempted. Traps may thus be used under some circumstances such as in the control of birds considered as pests. Some international treaties aim to protect migratory species across national boundaries. Some organizations work to protect birds from trappers. Several organizations have emerged to identify and remove traps and help authorities. Among the volunteer organizations are Lega per l´Abolizione della Caccia (League for the Abolition of Hunting), Centro Soccorso Animali Modena (CSA) Modena (Fauna Rescue Centre Modena), World Wide Fund for Nature (WWF Italia), and LIPU (Lega Italiana Protezione Uccelli or Italian League for Bird Protection, Naples) One volunteer organization removed 150,000 illegal traps during a ten-year span.

In Europe, the 1979 Birds Directive and its amendments seeks to protect wild birds and allows hunting only within certain limits. According to the Directive use of traps, bird lime (glue), nets, live decoys and poison is forbidden at all times and birds are protected during breeding and spring migration. Malta joined the European Union in 2004 and obtained certain exemptions from the protective laws that apply to the membership states regarding wild birds. Trapping of several types of finches was allowed for five years until 2009 when the derogation was phased out. Malta had about 4,700 licensed trappers in 2007 who, by exemption from European protective laws, continue to trap quail, Turtle Doves, golden plovers and Song Thrushes. Further, illegal trapping continues to be a problem in Malta. In North America the Migratory Bird Treaty Act of 1918 and its amendments protect wild birds.

Ecological impact

Trapping can devastate local bird populations and also impact migrants at critical stopover sites. In Malta three local species have been extirpated by trappers and hunters—the Peregrine Falcon, the Barn Owl and the jackdaw. Jonathan Franzen has called Malta "the most savagely bird-hostile place in Europe". Trapping also affects migratory birds at important stopover sites such as the Maltese islands. However, one book claims that Peregrine falcons have again started to breed successfully since 2009 in Malta and that the main hunting organisation openly speaks against illegal hunting and trapping. The author also suggests that claims by Birdlife are often exaggerated.