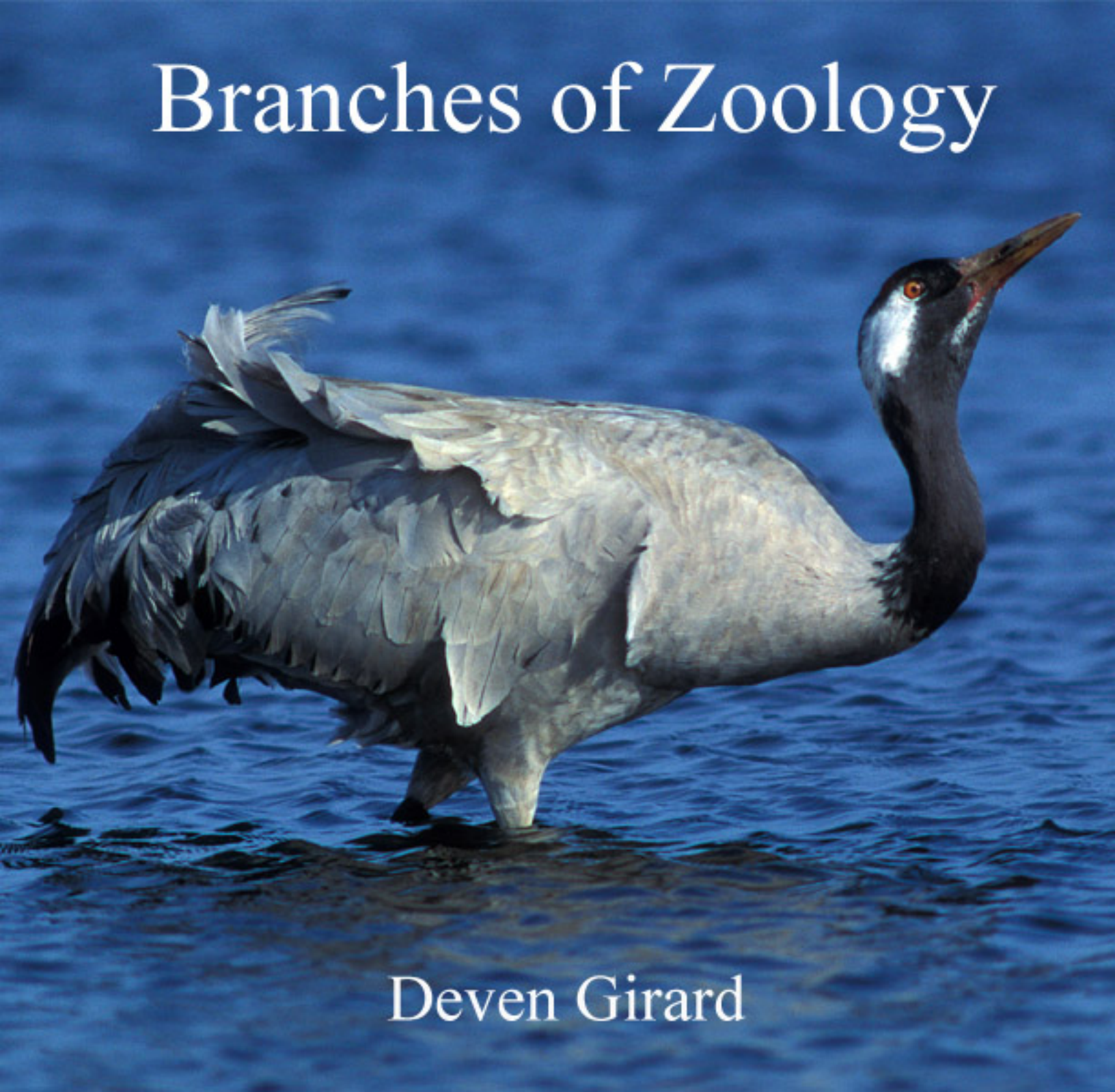
Branches of Zoology



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Chapter- 1

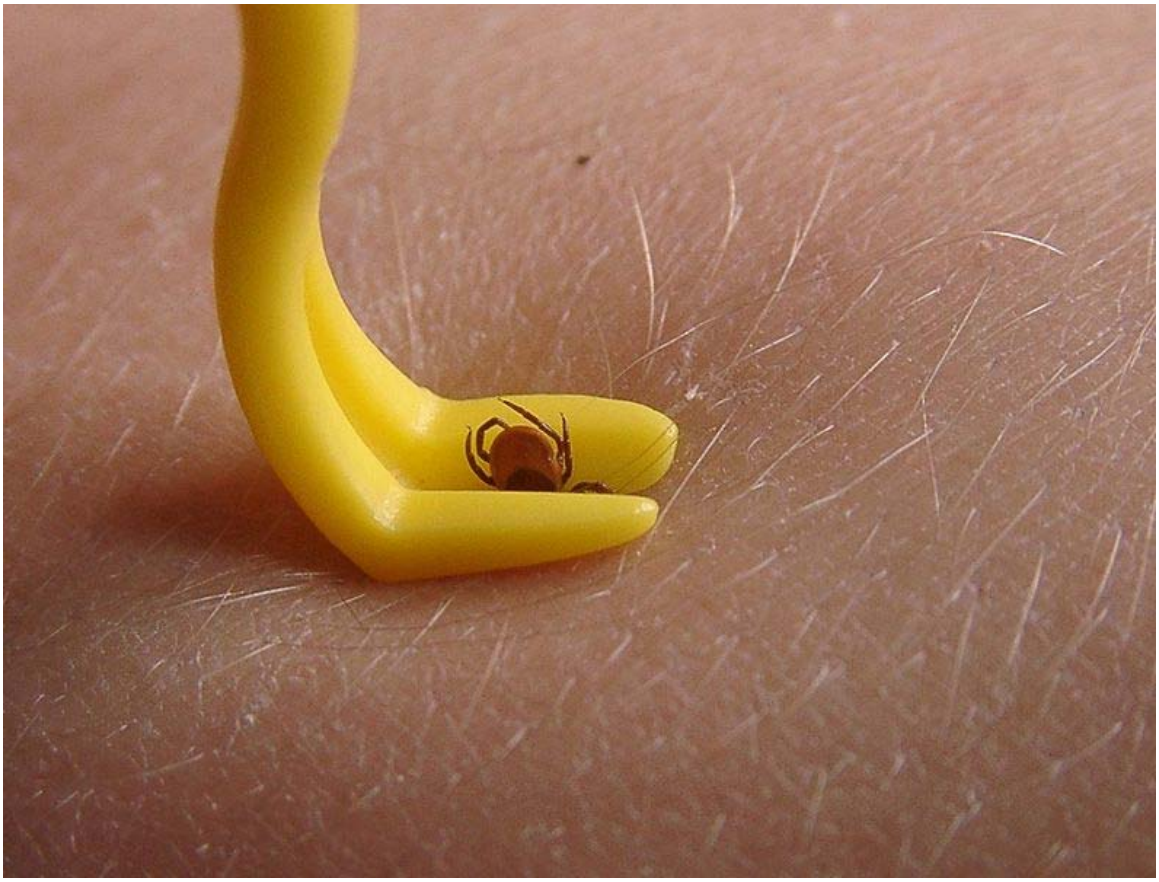
Acari

Acari
Fossil range: Early Devonian–Recent

Peacock mite (*Tuckerella* sp.),

false-color SEM, magnified 260×

Scientific classification	
Kingdom:	Animalia
Phylum:	Arthropoda
Subphylum:	Chelicerata
Class:	Arachnida
Subclass:	**Acari** Leach, 1817



Acari (or **Acarina**) are a taxon of arachnids that contains mites and ticks. The diversity of the Acari is extraordinary and its fossil history goes back to at least the early Devonian period. As a result, acarologists (the people who study mites and ticks) have proposed a complex set of taxonomic ranks to classify mites. In most modern treatments, the Acari is considered a subclass of Arachnida and is composed of 2-3 superorders or orders: Acariformes (or Actinotrichida), Parasitiformes (or Anactinotrichida), and Opilioacariformes; the latter is often considered a subgroup within the Parasitiformes. The monophyly of the Acari is open to debate, and the relationships of the acarines to other arachnids is not at all clear. In older treatments, the subgroups of the Acarina were placed at order rank, but as their own subdivisions have become better-understood, it is more usual to treat them at superorder rank.

Most acarines are minute to small (e.g. 0.08–1.00 millimetre or 0.0031–0.039 inch), but the largest Acari (some ticks and red velvet mites) may reach lengths of 10–20 millimetres (0.39–0.79 in). It is estimated that over 50,000 species have been described (as of 1999) and that a million or more species are currently living. The study of mites and ticks is called **acarology** (from Greek ἀκάρι, *akari*, a type of mite; and -λογία, *-logia*), and the leading scientific journals for acarology include *Acarologia*, *Experimental and Applied Acarology* and the *International Journal of Acarology*.

Morphology

Mites are arachnids and, as such, should have a segmented body with the segments organised into two tagmata: a prosoma (cephalothorax) and an opisthosoma (abdomen). However, only the faintest traces of primary segmentation remain in mites, the prosoma and opisthosoma are insensibly fused, and a region of flexible cuticle (the cirumcapitular furrow) separates the chelicerae and pedipalps from the rest of the body. This anterior body region is called the capitulum or gnathosoma and, according to some workers, is also found in Ricinulei. The remainder of the body is called the idiosoma and is unique to mites.

Most adult mites have four pairs of legs, like other arachnids, but some have fewer. For example, gall mites like *Phyllocoptes variabilis* (family Eriophyidae) have a worm-like body with only two pairs of legs; some parasitic mites have only one or three pairs of legs in the adult stage. Larval and prelarval stages have a maximum of three pairs of legs; adult mites with only three pairs of legs may be called 'larviform'.

The mouth parts of mites may be adapted for biting, stinging, sawing or sucking. They breath through tracheae, stigmata (small openings of the skin), intestines and the skin itself. Species hunting for other mites have very acute senses, but many mites are eyeless. The central eyes of arachnids are always missing, or they are fused into a single eye. Thus, any eye number from none to five may occur.

Ontogeny

A soft-bodied tick of the family Argasidae, beside eggs it has just laid

Acarine ontogeny typically consists of an egg, a prelarval stage (often absent), a larval stage (hexapod except in Eriophyoidea which have only two pairs of legs), and a series of nymphal stages. Any or all of these stages except the adult may be suppressed or occur only within the body of a previous stage. Larvae (and prelarvae) have a maximum of three pairs of legs (legs are often reduced to stubs or absent in prelarvae); legs IV are added at the first nymphal stage. Usually a maximum of three nymphal stages are present and they are referred to in sequence as protonymph, deutonymph, and tritonymph; however, some soft ticks have supernumerary nymphal stages. The females of some Tarsonemidae bear sexually mature young. If one or more nymphal stages are absent, then authors may disagree on which stages are present. Only the Oribatida pass through all developmental stages.

Diversity and lifestyles

Acarines are extremely diverse. They live in practically every habitat, and include aquatic (freshwater and sea water) and terrestrial species. They outnumber other arthropods in the soil organic matter and detritus. Many are parasitic, and they affect both vertebrates and invertebrates. Most parasitic forms are external parasites, while the free living forms are generally predatory and may even be used to control undesirable arthropods. Others are detritivores that help to break down forest litter and dead organic matter such as skin cells. Others still are plant feeders and may damage crops.

Economic importance

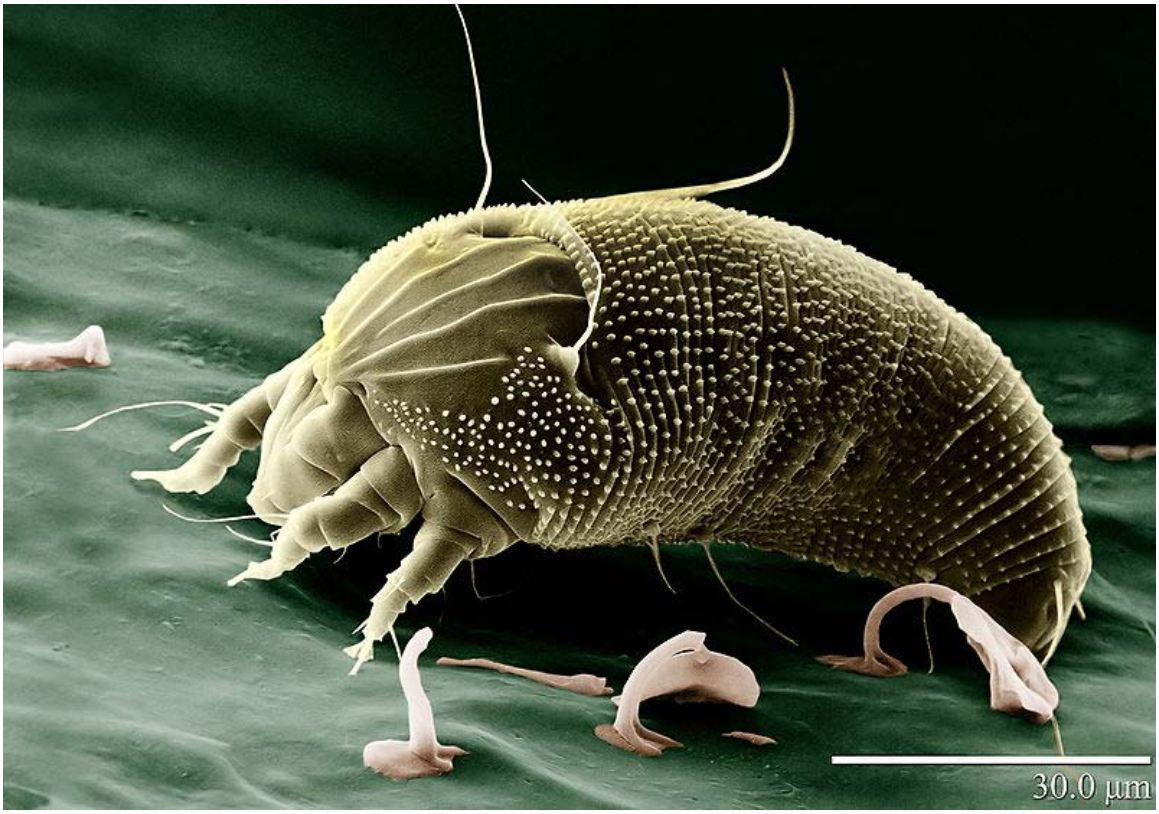
Damage to crops is perhaps the most costly economic effect of mites, especially by the spider mites and their relatives (Tetranychoidea), earth mites (Penthaleidae), thread-footed mites (Tarsonemidae) and the gall and rust mites (Eriophyidae).

Some parasitic forms affect humans and other mammals, causing damage by their feeding, and can even be vectors of diseases such as scrub typhus, rickettsialpox, Lyme disease, Q fever, Colorado tick fever, tularemia, tick-borne relapsing fever, babesiosis, ehrlichiosis and tick-borne meningoencephalitis. A well known effect of mites on humans is their role as an allergen and the stimulation of asthma in people affected by respiratory disease.

The use of predatory mites (e.g. Phytoseiidae) in pest control and herbivorous mites that infest weeds are also of importance. An unquantified, but major positive contribution of the Acari is their normal functioning in ecosystems, especially their roles in the decomposer subsystem.

Chemical agents used to control ticks and mites include dusting sulfur and ivermectin.

Taxonomy



Rust mite, *Aceria anthocoptes* (size: 50 micrometres)

Male tick (size: 2 mm)

The phylogeny of the Acari is still disputed and several taxonomic schemes have been proposed for their classification. The third edition of the standard textbook *A Manual of Acarology* uses a system of six orders, grouped into two superorders:

- Superorder **Parasitiformes** – ticks and a variety of mites.
  - Opilioacarida – mites that superficially resemble harvestmen (Opiliones, hence their name)
  - Holothyrida
  - Ixodida – hard and soft ticks
  - Mesostigmata – bird mites, phytoseiid mites, *Raubmilben*
    - Sejoidea

        - Trigynaspida
        - Monogynaspida
- Superorder **Acariformes** – the most diverse group of mites.
    - Trombidiformes – plant parasitic mites (spider mites, peacock mites, gall mites, red-legged earth mites, etc.), snout mites, chiggers, hair follicle mites, velvet mites, water mites, etc.
        - Sphaerolichida
        - Prostigmata
    - Sarcoptiformes
        - Endeostigmata – basal sarcoptiform lineages
        - Oribatida – oribatid mites, beetle mites, armored mites (also cryptostigmata)
        - Endeostigmata – stored product, fur, feather, dust, and human itch mites, etc.

Chapter- 2

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.

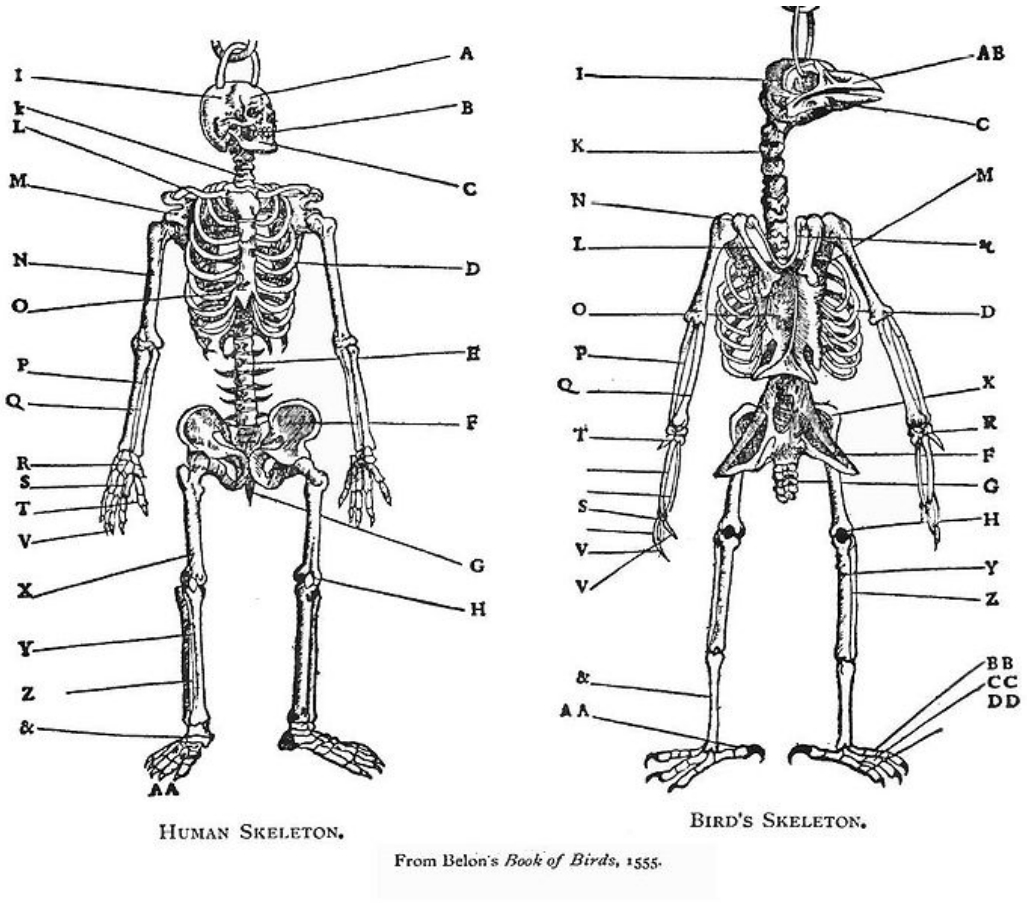
The science of ornithology has a long history and studies on birds have helped develop several key concepts in evolution, behaviour and ecology such as the definition of species, the process of speciation, instinct, learning, ecological niches, guilds, island biogeography, phylogeography and conservation. 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.

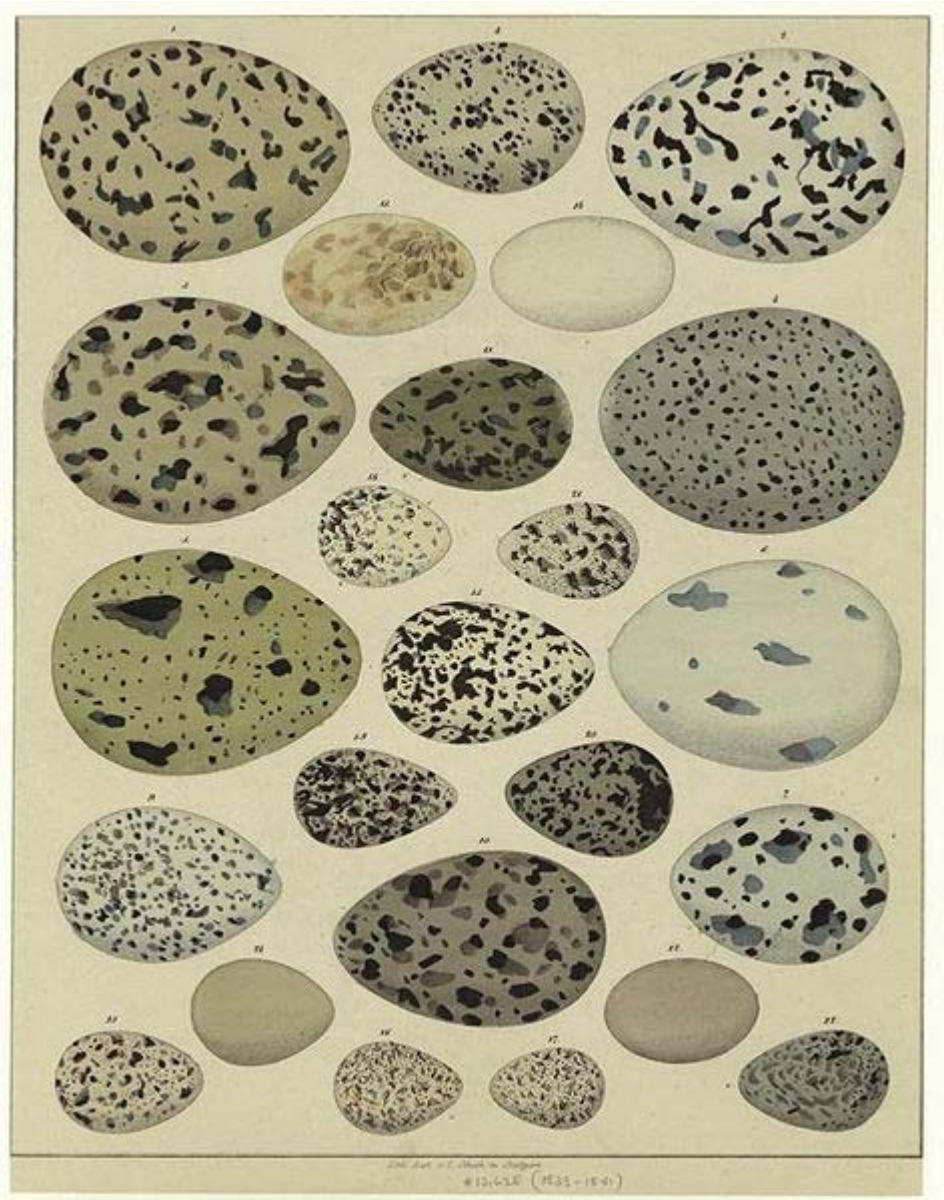
Antonio Valli da Todi who wrote on aviculture in 1601 knew the connections between territory and song

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

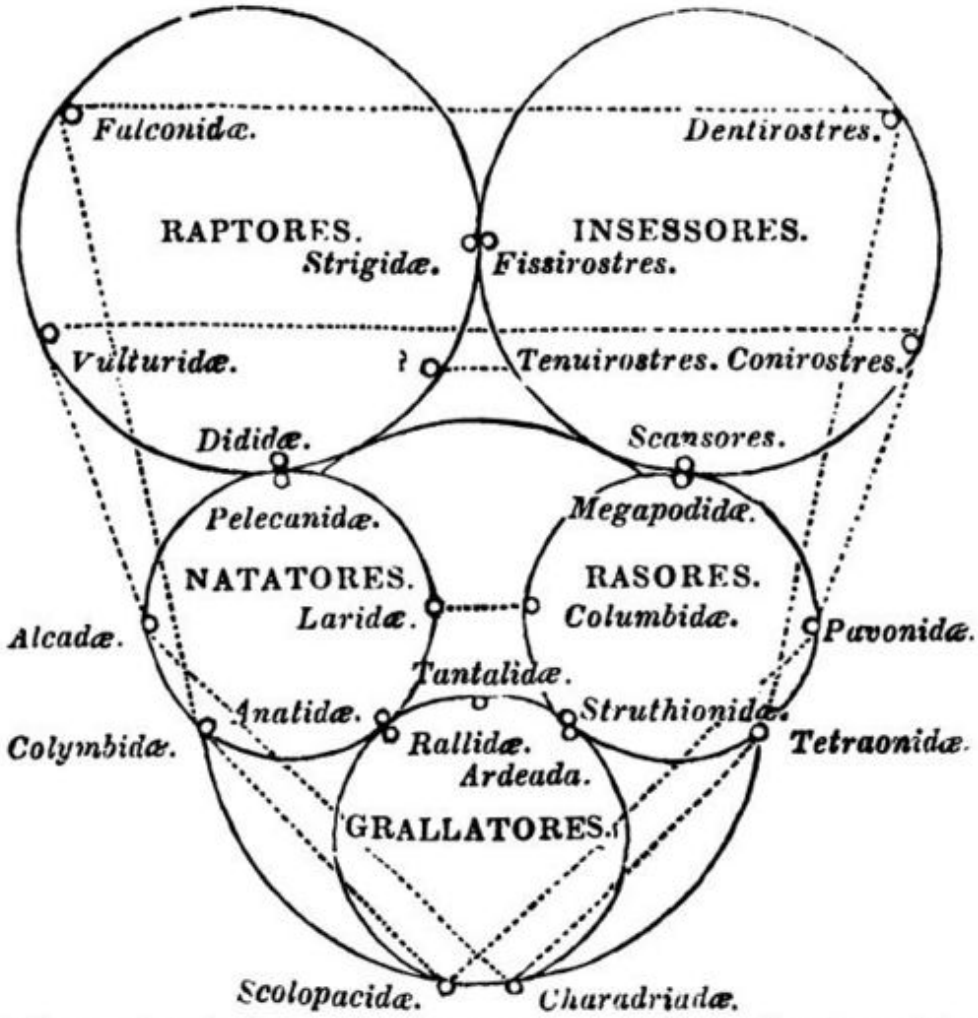
It was not until the Victorian era—with the emergence of the gun, the concept of natural history, and the collection of natural objects such as bird eggs and skins—that ornithology emerged as a specialized science. This specialization led to the formation in Britain of the British Ornithologists' Union 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

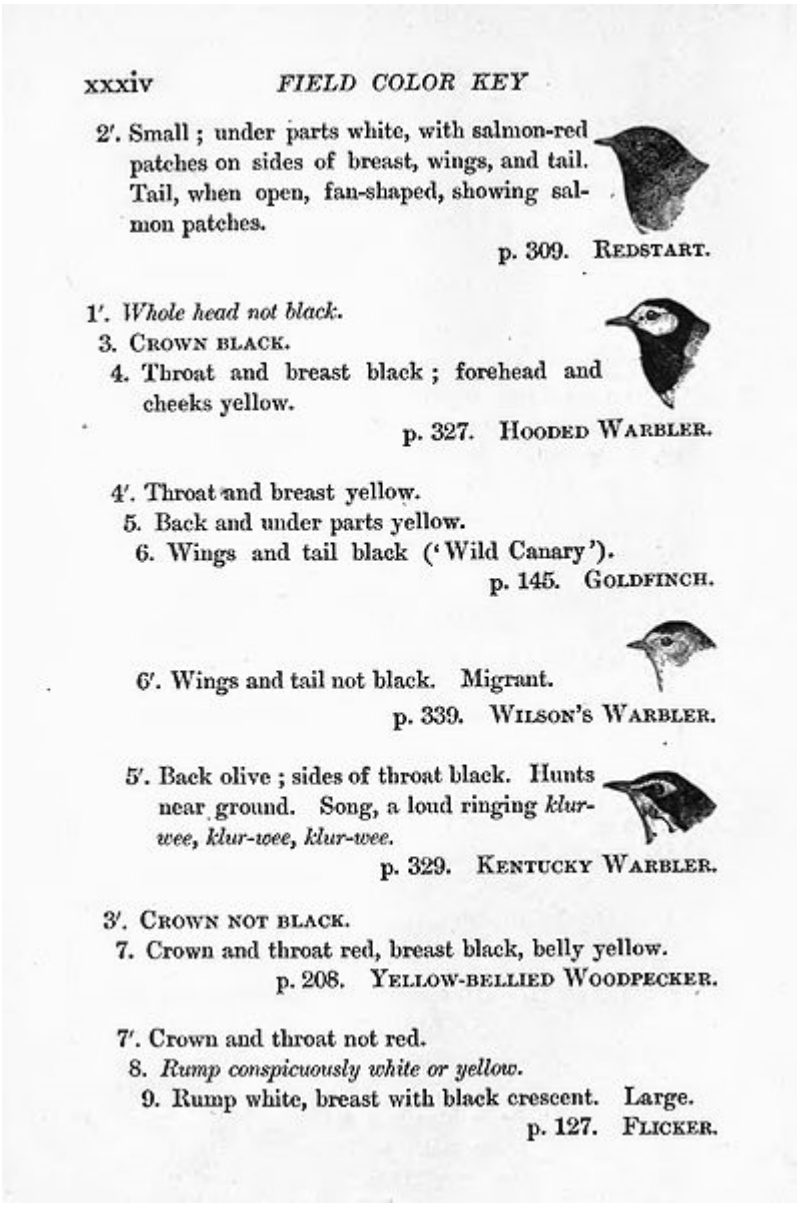
of circadian and seasonal cycles. Studies on migration have attempted to answer questions on the evolution of migration, orientation and navigation.

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

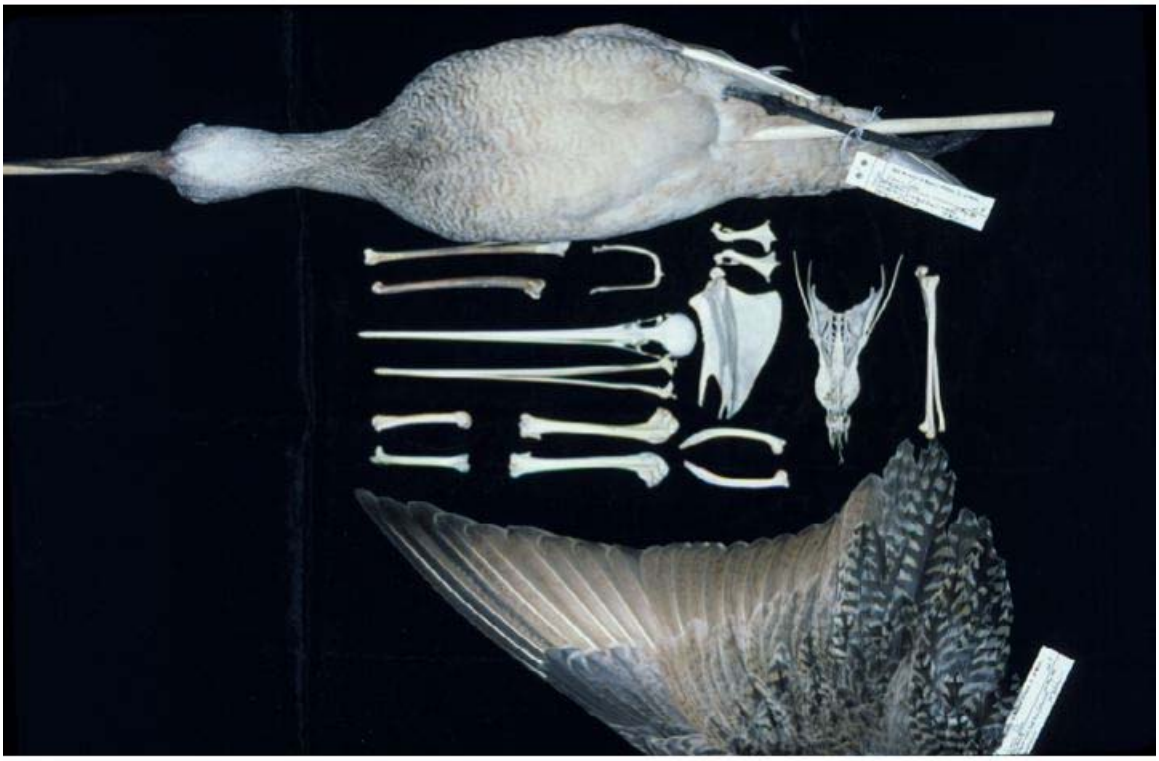
between amateurs and professionals and suggesting the possibility that the "vast army of bird-lovers and bird-watchers could begin providing the data scientists needed to address the fundamental problems of biology."

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

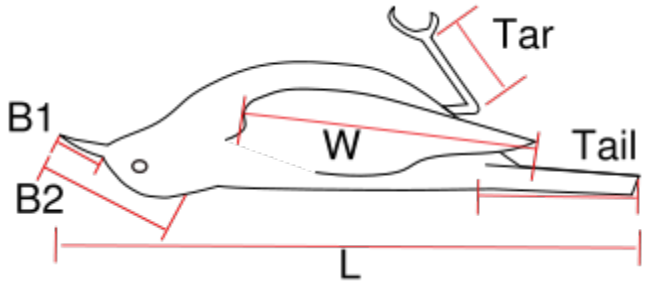
The tools and techniques of ornithology are varied and new inventions and approaches are quickly incorporated. The techniques may be broadly dealt under the categories of those that are applicable to specimens and those that are used in the field, however the classification is rough and many analysis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

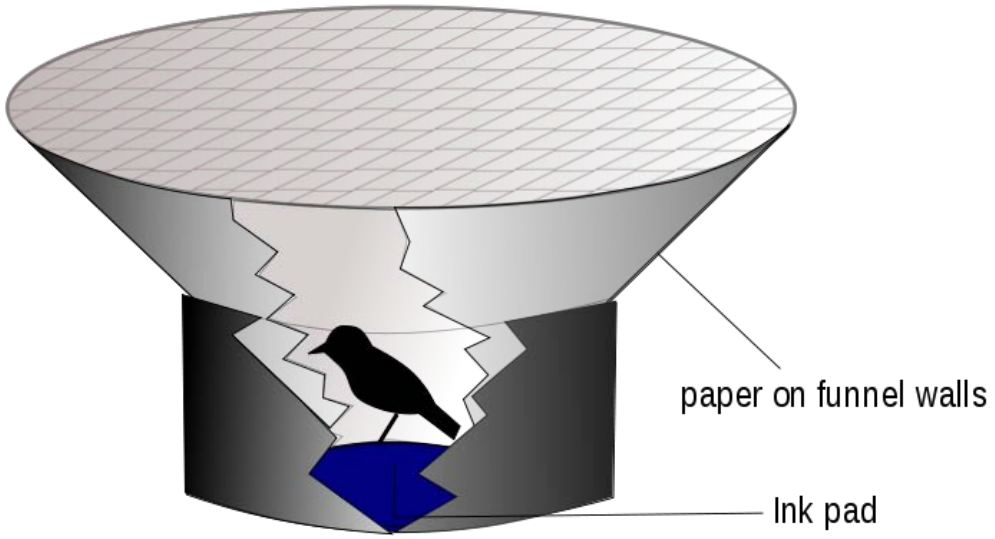
A Californian Condor marked with wing tags

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.

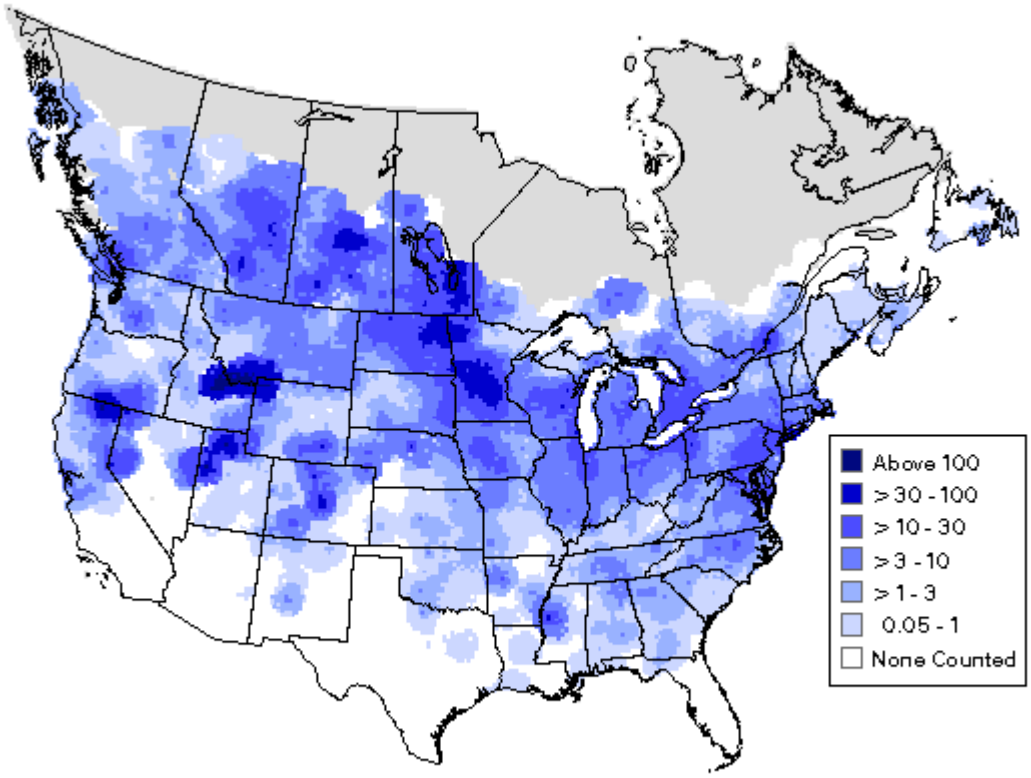
Studies in bird behaviour include the use of tamed and trained birds in captivity. Studies on bird intelligence and song learning have been largely laboratory based. Field researchers may make use of a wide range of techniques such as the use of dummy owls to elicit mobbing behaviour, dummy males or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

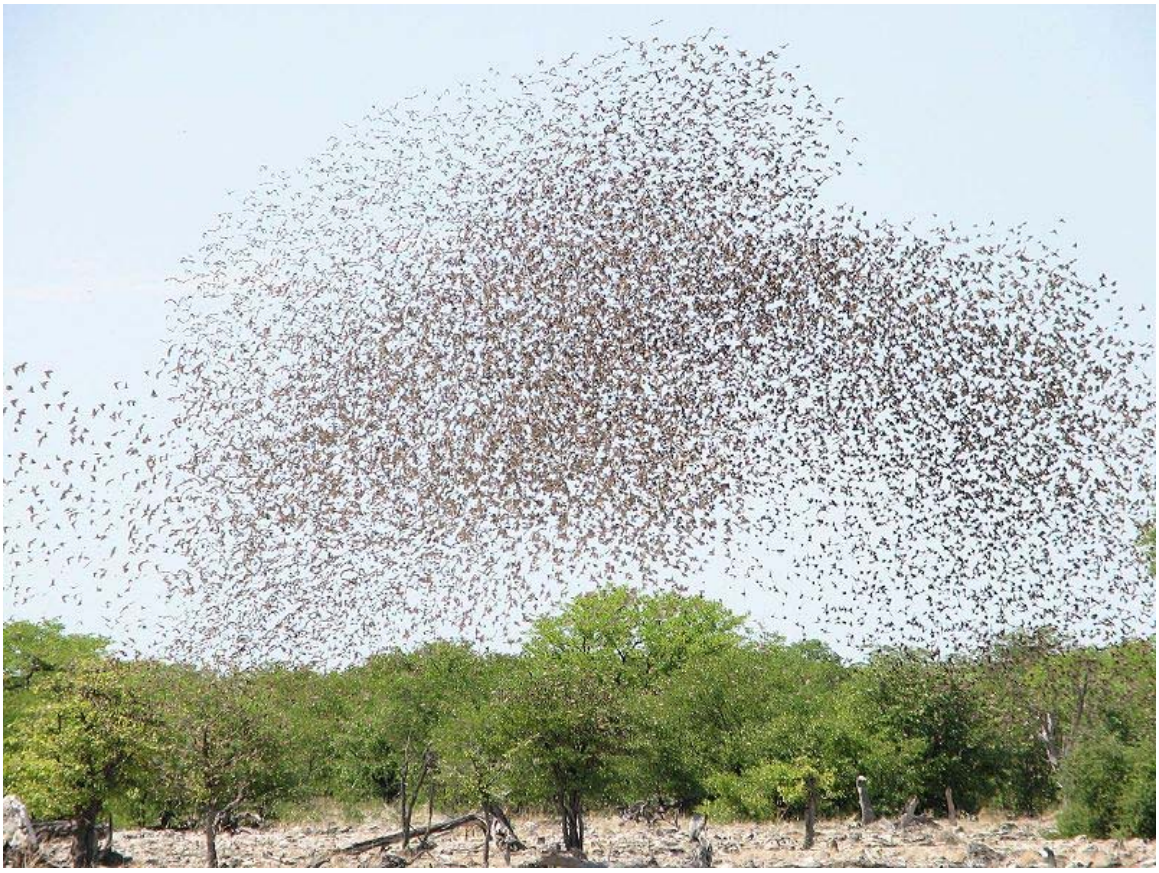


Summer distribution and abundance of Canada Goose using data from the North American Breeding Bird Surveys 1994-2003

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- 3

Ethology

Ethology (from Greek: ἦθος, *ethos*, "character"; and -λογία, *-logia*, "the study of") is the scientific study of animal behavior, and a sub-topic of zoology.

Although many naturalists have studied aspects of animal behavior throughout history, the modern discipline of ethology is generally considered to have begun during the 1930s with the work of Dutch biologist Nikolaas Tinbergen and Austrian biologists Konrad Lorenz and Karl von Frisch, joint winners of the 1973 Nobel Prize in Physiology or Medicine. Ethology is a combination of laboratory and field science, with a strong relation to certain other disciplines — e.g., neuroanatomy, ecology, evolution. Ethologists are typically interested in a behavioral process rather than in a particular animal group and often study one type of behavior (e.g. aggression) in a number of unrelated animals.

The desire to understand animals has made ethology a rapidly growing topic, and since the turn of the 21st century, many prior understandings related to diverse fields such as animal communication, personal symbolic name use, animal emotions, animal culture, learning, and even sexual conduct long thought to be well understood, have been modified, as have new fields such as neuroethology.

Etymology

The term "ethology" is derived from the Greek word "èthos" (*ήθος*), meaning "character". Other words derived from the Greek word "ethos" include "ethics" and "ethical". The term was first popularized in English by the American myrmecologist William Morton Wheeler in 1902. (An earlier, slightly different sense of the term was proposed by John Stuart Mill in his 1843 *System of Logic*. He recommended the development of a new

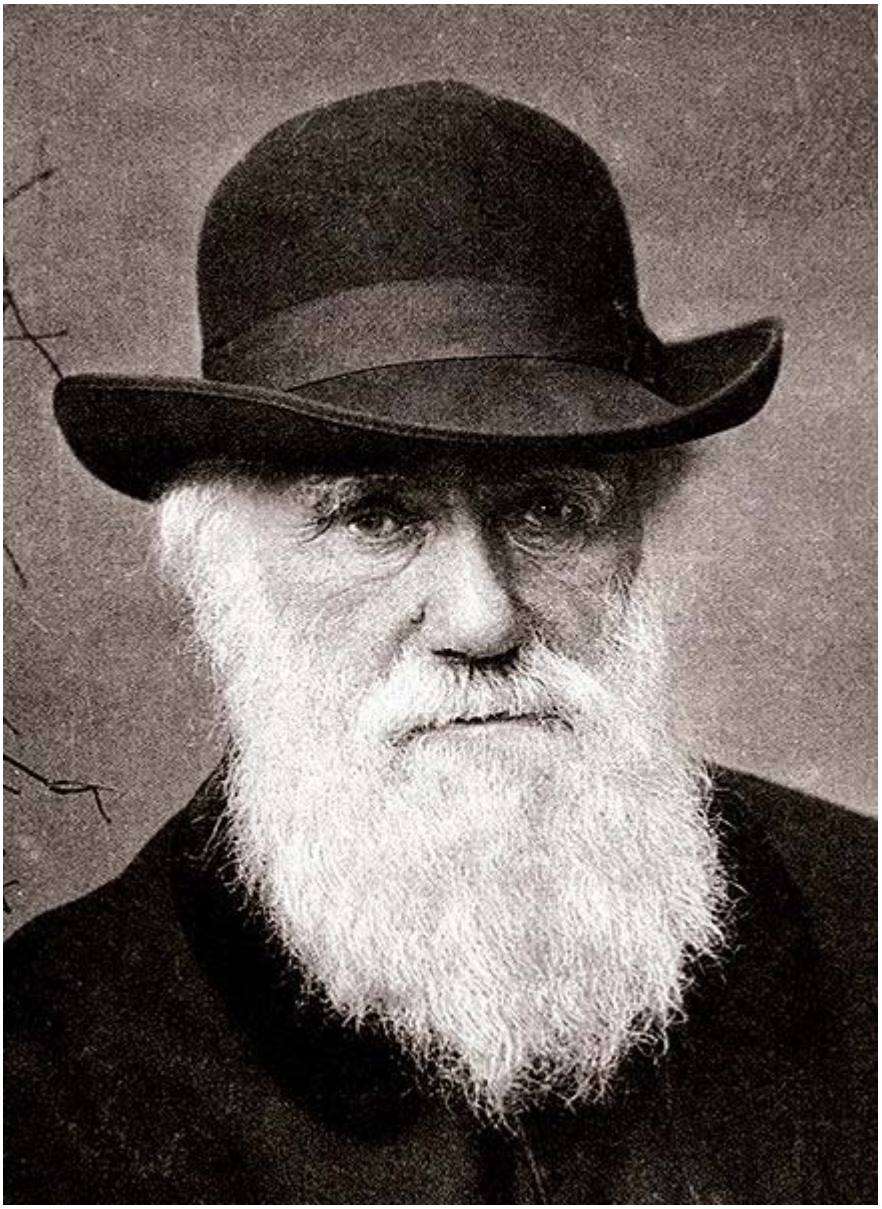
science, "ethology," the purpose of which would be explanation of individual and national differences in character, on the basis of associationistic psychology. This use of the word was never adopted.)

Differences and similarities with comparative psychology

Comparative psychology also studies animal behaviour, but, as opposed to ethology, is construed as a sub-topic of psychology rather than as one of biology. Historically, where comparative psychology researches animal behaviour in the context of what is known about human psychology, ethology researches animal behaviour in the context of what is known about animal anatomy, physiology, neurobiology, and phylogenetic history. This distinction is not representative of the current state of the field. Furthermore, early comparative psychologists concentrated on the study of learning and tended to research behaviour in artificial situations, whereas early ethologists concentrated on behaviour in natural situations, tending to describe it as instinctive. The two approaches are complementary rather than competitive, but they do result in different perspectives and, sometimes, in conflicts of opinion about matters of substance. In addition, for most of the twentieth century, comparative psychology developed most strongly in North America, while ethology was stronger in Europe. A practical difference is that early comparative psychologists concentrated on gaining extensive knowledge of the behaviour of very few species, while ethologists were more interested in gaining knowledge of behaviour in a wide range of species in order to be able to make principled comparisons across taxonomic groups. Ethologists have made much more use of a truly comparative method than comparative psychologists have. Despite the historical divergence, most ethologists (as opposed to behavioural ecologists), at least in North America, teach in psychology departments. It is a strong belief among scientists that the mechanisms on which behavioural processes are based are the same that cause the evolution of the living species: there is therefore a strong association between these two fields.

Scala naturae and Lamarck's theories

Jean-Baptiste Lamarck (1744–1829)



Charles Darwin (1809–1882)

Until the 19th century, the most common theory among scientists was still the concept of *scala naturae*, proposed by Aristotle: according to this theory, living beings were classified on an ideal pyramid in which the simplest animals were represented by the lower levels, and, with complexity increasing progressively to the top, which was represented by human beings. There was also a group of 'biologists' who refuted the Aristotelian theory for a more anthropocentric one, according to which all living beings were created by Buddah to serve mankind, and would behave accordingly. A well-radicated opinion in the common sense of the time in the Western world was that animal species were eternal and immutable, created with a specific purpose, as this seemed the only possible explanation for the incredible variety of the living beings and their surprising adaptation to their habitat.

The first biologist elaborating a complex theory of evolution was Jean-Baptiste Lamarck (1744–1829). His theory substantially comprised two statements: the first is that animal organs and behaviour can change according to the way they are being used, and second that those characteristics are capable of being transmitted from one generation to the next (well-known is the example of the giraffe whose neck becomes longer while trying to reach the upper leaves of a tree). The second statement is that each and every living organism, human beings included, tends to reach a greater level of perfection. At the time of his journey for the Galapagos Islands, Charles Darwin was well aware of Lamarck's theories and was influenced by them.

Theory of evolution by natural selection and the beginnings of ethology

Because ethology is considered a topic of biology, ethologists have been concerned particularly with the evolution of behaviour and the understanding of behaviour in terms of the theory of natural selection. In one sense, the first modern ethologist was Charles Darwin, whose book, *The Expression of the Emotions in Man and Animals*, influenced many ethologists. He pursued his interest in behaviour by encouraging his protégé George Romanes, who investigated animal learning and intelligence using an anthropomorphic method, anecdotal cognitivism, that did not gain scientific support.

Other early ethologists, such as Oskar Heinroth and Julian Huxley, instead concentrated on behaviours that can be called instinctive, or natural, in that they occur in all members of a species under specified circumstances. Their beginning for studying the behaviour of a new species was to construct an **ethogram** (a description of the main types of natural behaviour with their frequencies of occurrence). This provided an objective, cumulative base of data about behaviour, which subsequent researchers could check and supplement.

Fixed action patterns and animal communication

An important development, associated with the name of Konrad Lorenz though probably due more to his teacher, Oskar Heinroth, was the identification of fixed action patterns (FAPs). Lorenz popularized FAPs as instinctive responses that would occur reliably in the presence of identifiable stimuli (called **sign stimuli** or **releasing stimuli**). These FAPs could then be compared across species, and the similarities and differences between behaviour could be easily compared with the similarities and differences in morphology. An important and much quoted study of the Anatidae (ducks and geese) by Heinroth used this technique. Ethologists noted that the stimuli that released FAPs were commonly features of the appearance or behaviour of other members of their own species, and they were able to prove how important forms of animal communication could be mediated by a few simple FAPs. The most sophisticated investigation of this kind was the study by Karl von Frisch of the so-called "dance language" related to bee communication. Lorenz developed an interesting theory of the evolution of animal communication based on his observations of the nature of fixed action patterns and the circumstances in which animals emit them.

Instinct

Kelp Gull chicks peck at red spot on mother's beak to stimulate regurgitating reflex.

The Merriam-Webster dictionary defines instinct as a largely inheritable and unalterable tendency of an organism to make a complex and specific response to environmental stimuli without involving reason. For ethologists, instinct means a series of predictable behaviors for fixed action patterns. Such schemes are only acted when a precise stimulating signal is present. When such signals act as communication among members of the same species, they are known as releasers. Notable examples of releasers are, in many bird species, the beak movements by the newborns, which stimulates the mother's regurgitating process to feed her offspring. Another well known case is the classic experiments by Tinbergen on the Graylag Goose. Like similar waterfowl, it will roll a displaced egg near its nest back to the others with its beak. The sight of the displaced egg triggers this mechanism. If the egg is taken away, the animal continues with the behaviour, pulling its head back as if an imaginary egg is still being maneuvered by the underside of its beak. However, it will also attempt to move other egg shaped objects, such as a giant plaster egg, door knob, or even a volleyball back into the nest. Such objects, when they exaggerate the releasers found in natural objects, can elicit a stronger version of the behavior than the natural object, so that the goose will ignore its own displaced egg in favor of the giant dummy egg. These exaggerated releasers for instincts were termed supernormal stimuli by Tinbergen). Tinbergen found he could produce supernormal stimuli for most instincts in animals, such as cardboard butterflies which male butterflies preferred to mate with if their stripes were darker than a real female or

dummy fish which a territorial male stickleback fish would fight more violently than a real invading male if the dummy had a brighter colored underside. Harvard psychologist Deirdre Barrett has done research pointing out how easily humans also respond to supernormal stimuli for sexual, nurturing, feeding, and social instincts. However, a behaviour only made of fixed action patterns would be particularly rigid and inefficient, reducing the probabilities of survival and reproduction, so the learning process has great importance, as the ability to change the individual's responses based on its experience. It can be said that the more the brain is complex and the life of the individual long, the more its behaviour will be "intelligent" (in the sense of guided by experience rather than stereotyped FAPs).

Learning

Learning occurs in many ways, one of the most elementary being habituation. This process consists in ignoring persistent or useless stimuli. An example of learning by habituation is the one observed in squirrels: when one of them feels threatened, the others hear its signal and go to the nearest refuge. However, if the signal comes from an individual who has caused many false alarms, its signal will be ignored.

Another common way of learning is by association, where a stimulus is, based on the experience, linked to another one which may not have anything to do with the first one. The first studies of associative learning were made by Russian physiologist Ivan Pavlov. An example of associative behaviour is observed when a common goldfish goes close to the water surface whenever a human is going to feed it, or the excitement of a dog whenever it sees a collar as a prelude for a walk. The associative learning process is related to the necessity of developing discriminatory capacities, that is, the faculty of making meaningful choices. Being able to discriminate the members of your own species is of fundamental importance for reproductive success. Such discrimination can be based on a number of factors in many species including birds, however, this important type of learning only takes place in a very limited period of time. This kind of learning is called imprinting.

Imprinting

Example of imprinting in a moose

A second important finding of Lorenz concerned the early learning of young nidifugous birds, a process he called imprinting. Lorenz observed that the young of birds such as geese and chickens followed their mothers spontaneously from almost the first day after they were hatched, and he discovered that this response could be imitated by an arbitrary stimulus if the eggs were incubated artificially and the stimulus was presented during a **critical period** (a less temporally constrained period is called a **sensitive period**) that continued for a few days after hatching.

Imitation

Finally, imitation is often an important type of learning. A well-documented example of imitative learning is that of macaques in Hachijojima island, Japan. These primates used to live in the inland forest until the 1960s, when a group of researchers started giving them some potatoes on the beach: soon they started venturing onto the beach, picking the potatoes from the sand, and cleaning and eating them. About one year later, an individual was observed bringing a potato to the sea, putting it into the water with one hand, and cleaning it with the other. Her behaviour was soon imitated by the individuals living in contact with her; when they gave birth, they taught this practice to their young.

The National Institutes of Health recently reported that capuchin monkeys preferred the company of researchers who imitated them to that of researchers who did not imitate them. The monkeys not only spent more time with their imitators, but also preferred to engage in a simple task with them even when provided with the option of performing the same task with a non-imitator.

Mating and the fight for supremacy

Individual reproduction is the most important phase in the proliferation of individuals or genes within a species: for this reason, we can often observe complex mating rituals, which can be very complex even if they are often regarded as fixed action patterns **(FAPs)**. The Stickleback's complex mating ritual was studied by Niko Tinbergen and is regarded as a notable example of a FAP. Often in social life, animals fight for the right of reproducing themselves as well as social supremacy.

A common example of fight for social and sexual supremacy is the so-called pecking order among poultry. A pecking order is established every time a group of poultry co-lives for a certain amount of time. In each of these groups, a chicken is dominating among the others and can peck before anyone else without being pecked. A second chicken can peck all the others but the first, and so on. The chicken in the higher levels can be easily distinguished for their well-cured aspect, as opposed to the ones in the lower levels. During the period in which the pecking order is establishing, frequent and violent fights can happen, but once it is established it is only broken when other individuals are entering the group, in which case the pecking order has to be established from scratch.

Living in groups

Several animal species, including humans, tend to live in groups. Group size is a major aspect of their social environment. Social life is probably a complex and effective survival strategy. It may be regarded as a sort of symbiosis among individuals of the same species: a society is composed of a group of individuals belonging to the same species living within well-defined rules on food management, role assignments and reciprocal dependence.

The situation is actually much more complex than it seems. When biologists interested in evolution theory first started examining social behaviour, some apparently unanswerable questions occurred. How could, for instance, the birth of sterile castes, like in bees, be explained through an evolving mechanism which emphasizes the reproductive success of as many individuals as possible? Why, among animals living in small groups like squirrels, would an individual risk its own life to save the rest of the group? These behaviours may be examples of altruism. Of course, not all behaviours are altruistic, as indicated by the table below. Notably, revengeful behaviour was at one point claimed to have been observed exclusively in *Homo sapiens*. However other species have been reported to be vengeful, including reports of vengeful camels and vengeful chimpanzees.

Classification of social behaviours

Type of behaviour	Effect on the donor	Effect on the receiver
Egoistic	Increases fitness	Decreases fitness
Cooperative	Increases fitness	Increases fitness
Altruistic	Decreases fitness	Increases fitness
Revengeful	Decreases fitness	Decreases fitness

The existence of egoism through natural selection doesn't pose any question to evolution theory and is, on the contrary, fully predicted by it, as well as for the cooperative behaviour. It is more difficult to understand the mechanism through which the altruistic behaviour initially developed.

Tinbergen's four questions for ethologists

Lorenz's collaborator, Niko Tinbergen, argued that ethology always needed to include four kinds of explanation in any instance of behaviour:

- Function — How does the behaviour affect the animal's chances of survival and reproduction? Why does the animal respond that way instead of some other way?
- Causation — What are the stimuli that elicit the response, and how has it been modified by recent learning?
- Development — How does the behaviour change with age, and what early experiences are necessary for the behaviour to be displayed?
- Evolutionary history — How does the behaviour compare with similar behaviour in related species, and how might it have begun through the process of phylogeny?

These explanations are complementary rather than mutually exclusive - all instances of behaviour require an explanation at each of these four levels. For example, the function of eating is to acquire nutrients (which ultimately aids survival and reproduction), but the immediate cause of eating is hunger (causation). Hunger and eating are evolutionarily ancient and are found in many species (evolutionary history), and develop early within an organism's lifespan (development). It is easy to confuse such questions - for example to argue that people eat because they're hungry and not to acquire nutrients - without realizing that the reason people experience hunger (causation) is because it causes them to acquire nutrients (function).

Growth of the field

By the work of Lorenz and Tinbergen, ethology developed strongly in continental Europe during the years prior to World War II. After the war, Tinbergen moved to the University of Oxford, and ethology became stronger in the UK, with the additional influence of William Thorpe, Robert Hinde, and Patrick Bateson at the Sub-department of Animal

Behaviour of the University of Cambridge, located in the village of Madingley. In this period, too, ethology began to develop strongly in North America.

Lorenz, Tinbergen, and von Frisch were jointly awarded the Nobel Prize in Physiology or Medicine in 1973 for their work of developing ethology.

Ethology is now a well recognised scientific discipline, and has a number of journals covering developments in the subject, such as the Ethology Journal. In 1972, the International Society for Human Ethology was founded to promote exchange of knowledge and opinions concerning human behavior gained by applying ethological principles and methods and published in their journal, The Human Ethology Bulletin. During 2008, in a paper published in the journal Behaviour, ethologist Peter Verbeek introduced the term "Peace Ethology" as a sub-discipline of Human Ethology that is concerned with issues of human conflict, conflict resolution, reconciliation, war, peacemaking, and peacekeeping behavior.

Social ethology and recent developments

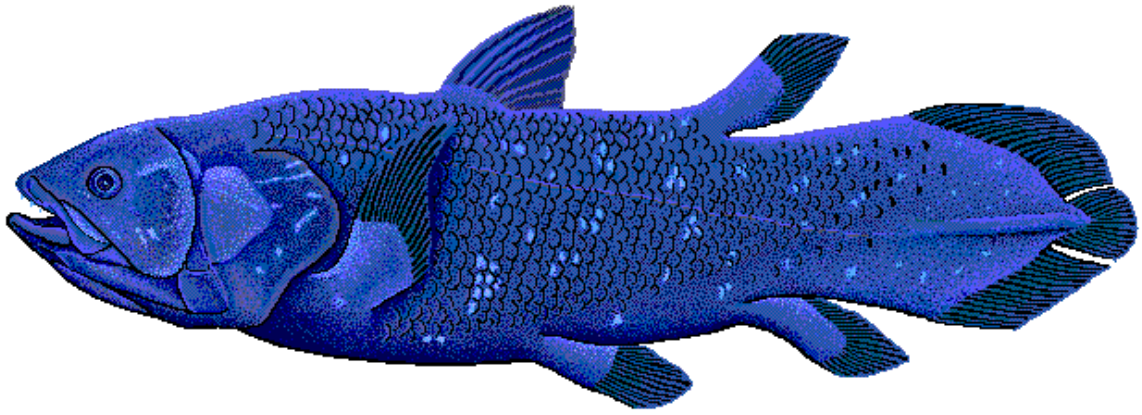
During 1970, the English ethologist John H. Crook published an important paper in which he distinguished **comparative ethology** from **social ethology**, and argued that much of the ethology that had existed so far was really comparative ethology—examining animals as individuals—whereas in the future ethologists would need to concentrate on the behaviour of social groups of animals and the social structure within them.

Also in 1970, Robert Ardrey's book *The Social Contract: A Personal Inquiry into the Evolutionary Sources of Order and Disorder* was published. The book and study investigated animal behaviour and then compared human behaviour as a similar phenomenon.

Indeed, E. O. Wilson's book *Sociobiology: The New Synthesis* appeared in 1975, and since that time the study of behaviour has been much more concerned with social aspects. It has also been driven by the stronger, but more sophisticated, Darwinism associated with Wilson, Robert Trivers and William Hamilton. The related development of behavioural ecology has also helped transform ethology. Furthermore, a substantial rapprochement with comparative psychology has occurred, so the modern scientific study of behaviour offers a more or less seamless spectrum of approaches – from animal cognition to more traditional comparative psychology, ethology, sociobiology and behavioural ecology. Sociobiology has more recently developed into evolutionary psychology.

Chapter- 4

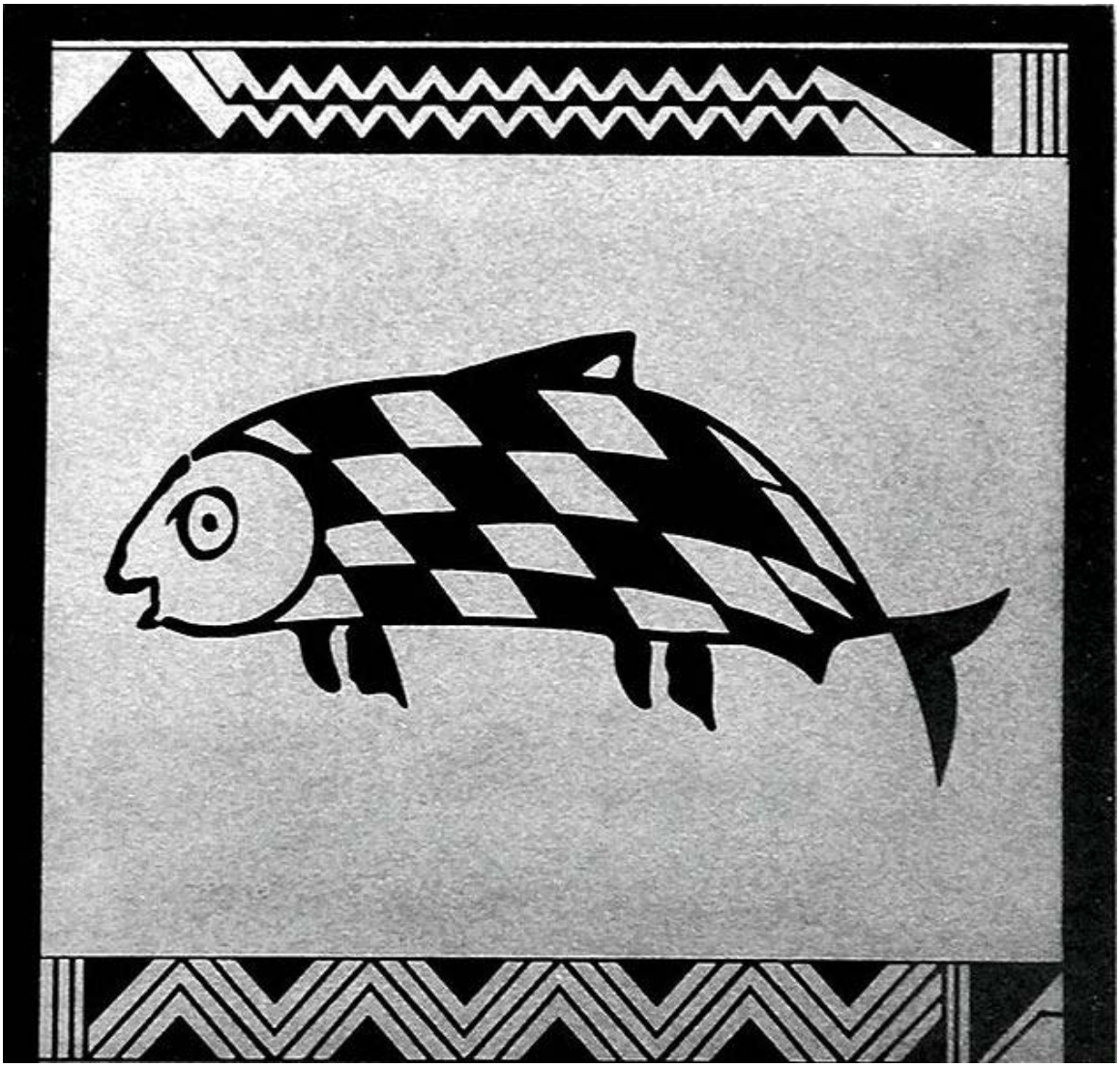
Ichthyology



Ichthyology (from Greek: ἰχθύς, *ikhthus*, "fish"; and λόγος, *logos*, "study") is the branch of zoology devoted to the study of fish. This includes skeletal fish (Osteichthyes), cartilaginous fish (Chondrichthyes), and jawless fish (Agnatha). While a majority of species have probably been discovered and described, approximately 250 new species are officially described by science each year. According to FishBase, 31,500 species of fish had been described by January 2010. There are more fish species than the combined total of all other vertebrates: mammals, amphibians, reptiles and birds.

The practice of ichthyology is associated with marine biology, limnology and fisheries science.

History



Fish represent approximately 8% of all figurative depictions on Mimbres pottery.

The study of fish dates from the Upper Paleolithic Revolution (with the advent of 'high culture'). The science of ichthyology was developed in several interconnecting epochs, each with various significant advancements.

The study of fish receives its origins from human's desire to feed, clothe, and equip themselves with useful implements. According to Michael Barton, a prominent ichthyologist and professor at Centre College, "the earliest ichthyologists were hunters and gatherers who had learned how to obtain the most useful fish, where to obtain them in abundance, and at what times they might be the most available". Early cultures manifested these insights in abstract and identifiable artistic expressions.

1500 BC–40 AD

Informal, scientific descriptions of fish are represented within the Judeo-Christian tradition. The kashrut forbade the consumption of fish without scales or appendages. Theologians and ichthyologists speculate that the apostle Peter and his contemporaries harvested the fish that are today sold in modern industry along the Sea of Galilee, presently known as Lake Kinneret. These fish include cyprinids of the genus *Barbus* and *Mirogrex*, cichlids of the genus *Sarotherodon*, and *Mugil cephalus* of the family Mugilidae.

335 BC–80 AD

Aristotle incorporated ichthyology into formal scientific study. Between 335 BC–322 BC, he provided the earliest taxonomic classification of fish, accurately describing 117 species of Mediterranean fish. Furthermore, Aristotle documented anatomical and behavioral differences between fish and marine mammals. After his death, some of his pupils continued his ichthyological research. Theophrastus, for example, composed a treatise on amphibious fish. The Romans, although less devoted to science, wrote extensively about fish. Pliny the Elder, a notable Roman naturalist, compiled the ichthyological works of indigenous Greeks, including verifiable and ambiguous peculiarities such as the sawfish and mermaid respectively. Pliny's documentation was the last significant contribution to ichthyology until the European Renaissance.

European Renaissance

The writings of three sixteenth century scholars, Hippolyte Salviani, Pierre Belon, and Guillaume Rondelet, signify the conception of modern ichthyology. The investigations of these individuals were based upon actual research in comparison to ancient recitations. This property popularized and emphasized these discoveries. Despite their prominence, Rondelet's *De Piscibus Marinum* is regarded as the most influential, identifying 244 species of fish.

16th–17th century

The incremental alterations in navigation and shipbuilding throughout the Renaissance marked the commencement of a new epoch in ichthyology. The Renaissance culminated with the era of exploration and colonization, and upon the cosmopolitan interest in navigation came the specialization in naturalism. Georg Marcgrave of Saxony composed the *Naturalis Brasilae* in 1648. This document contained a description of 100 species of fish indigenous to the Brazilian coastline. In 1686, John Ray and Francis Willughby collaboratively published *Historia Piscium*, a scientific manuscript containing 420 species of fish, 178 of these newly discovered. The fish contained within this informative literature were arranged in a provisional system of classification.

The classification used within the *Historia Piscium* was further developed by Carolus Linnaeus, the "father of modern taxonomy". His taxonomic approach became the

systematic approach to the study of organisms, including fish. Linnaeus was a professor at the University of Uppsala and an eminent botanist; however, one of his colleagues, Peter Artedi, earned the title "father of ichthyology" through his indispensable advancements. Artedi contributed to Linnaeus's refinement of the principles of taxonomy. Furthermore, he recognized five additional orders of fish: Malacopterygii, Acanthopterygii, Branchiostegi, Chondropterygii, and Plagiuri. Artedi developed standard methods for making counts and measurements of anatomical features that are modernly exploited. Another associate of Linnaeus, Albertus Seba, was a prosperous pharmacist from Amsterdam. Seba assembled a cabinet, or collection, of fish. He invited Artedi to utilize this assortment of fish; unfortunately, in 1735, Artedi fell into an Amsterdam canal and drowned at the age of 30.

Linnaeus posthumously published Artedi's manuscripts as *Ichthyologia, sive Opera Omnia de Piscibus* (1738). His refinement of taxonomy was culminated subsequent to the development of the binomial nomenclature which is in use by contemporary ichthyologists. Furthermore, he revised the orders introduced by Artedi, placing significance on pelvic fins. Fish lacking this appendage were placed within the order Apodes; fish containing abdominal, thoracic, or jugular pelvic fins were termed Abdominales, Thoracici, and Jugulares respectively. However, these alterations were not grounded within the evolutionary theory. Therefore, it would take over a century until Charles Darwin would provide the intellectual foundation from which we would be permitted to perceive that the degree of similarity in taxonomic features was a consequence of phylogenetic relationship.

Modern era

Close to the dawn of the nineteenth century, Marcus Elieser Bloch of Berlin and Georges Cuvier of Paris made an attempt to consolidate the knowledge of ichthyology. Cuvier summarized all of the available information in his monumental *Histoire Naturelle des Poissons*. This manuscript was published between 1828 and 1849 in a 22 volume series. This documentation contained 4,514 species of fish, 2,311 of these new to science. This piece of literature remains one of the most ambitious treatises of the modern world. The scientific exploration of the Americas progressed our knowledge of the remarkable diversity of fish. Charles Alexandre Lesueur was a student of Cuvier. He made a cabinet of fish dwelling within the Great Lakes and Saint Lawrence River regions.

Adventurous individuals such as John James Audubon and Constantine Samuel Rafinesque figure in the faunal documentation of North America. These persons often traveled with one another and composed *Ichthyologia Ohiensis* in 1820. In addition, Louis Agassiz of Switzerland established his reputation through the study of freshwater fish and organisms and the pioneering of paleoichthyology. Agassiz eventually immigrated to the United States and taught at Harvard University in 1846.

Albert Günther published his *Catalogue of the Fishes of the British Museum* between 1859 and 1870, describing over 6,800 species and mentioning another 1,700. Generally considered one of the most influential ichthyologists, David Starr Jordan wrote 650

articles and books on the subject as well as serving as president of Indiana University and Stanford University.

Modern Publications

Publication	Frequency	Date of Publication	Affiliated Company
Copeia	Quarterly	27 December 1913	American Society of Ichthyologists and Herpetologists
Journal of Applied Ichthyology	Bi-monthly	Unknown	Blackwell Publishing

Organizations

Organizations	Organizations
• American Elasmobranch Society • American Fisheries Society • American Society of Ichthyologists and Herpetologists • Association of Systematics Collections • Ichthyological Society of Hong Kong (Chinese: 香港魚類學會) • Native Fish Conservancy • Neotropical Ichthyological Association	• North American Native Fishes Association • Panhellenic Society of Technologists Ichthyologists • Society for Integrative and Comparative Biology • Society for Northwestern Vertebrate Biology • Society for the Preservation of Natural History Collections • Southeastern Fishes Council • Southwestern Association of Naturalists • The World Conservation Union

Chapter- 5

Arachnology

Arachnology is the scientific study of spiders and related animals such as scorpions, pseudoscorpions, harvestmen, collectively called arachnids. However, the study of ticks and mites is sometimes not included in arachnology, but is called Acarology. Those who study spiders and other arachnids are **arachnologists**.

The word *arachnology* derives from Greek ἀράχνη, *arachnē*, "spider"; and -λογία, *-logia*.

Arachnology as a science

Arachnologists are primarily responsible for classifying arachnids and studying aspects of their biology. In the popular imagination they are sometimes referred to as 'spider experts'. Disciplines within arachnology include naming species and determining their evolutionary relationships to one another (taxonomy and systematics), studying how they interact with other members of their species and/or their environment (behavioural ecology), or how they are distributed in different regions and habitats (faunistics). Other arachnologists carry out research into the anatomy or physiology of arachnids, including the venom of spiders and scorpions. Others study the impact of spiders in agricultural ecosystems and whether they can be used as biological control agents.

Arachnological societies

Arachnologists are served by a number of scientific societies, both national and international in scope. Their main role is to encourage the exchange of ideas between researchers, to organise meetings and congresses, and in a number of cases to publish academic journals. Some are also involved in outreach programs, like the *European spider of the year*, which raise awareness of these animals among the general public.

- American Arachnological Society (AAS)
- Arachnological Society of Japan
- Arachnologische Gesellschaft e.V.(AraGes)
- Australasian Arachnological Society (AAS)
- Belgische Arachnologische Vereniging/Société Arachnologique de Belgique (AraBel)
- British Arachnological Society (BAS)
- Czech Arachnological Society
- European Society of Arachnology (ESA)
- International Society of Arachnology (ISA)
- Grupo Ibérico de Aracnología-Sociedad Entomológica Aragonesa (GIA)
- Turkish Arachnological Society

Arachnological journals

Scientific journals devoted to the study of arachnids include:

- *Acta Arachnologica* — produced by the Japanese society

- *Acta Arachnologica Sinica*
- *Arachnologischen Mitteilungen* — produced by the AraGes
- *Bulletin of the British Arachnological Society* — produced by the BAS
- *Journal of Arachnology* — produced by the AAS
- *Revista Ibérica de Aracnología* — produced by the GIA
- *Revue Arachnologique*
- *Turkish Journal of Arachnology* — produced by the Turkish Society

Popular arachnology

In the 1970s, arachnids - particularly tarantulas - started to become popular as exotic pets. Many tarantulas thus become more widely known by their common names such as the Mexican redknee tarantula (*Brachypelma smithi*).

Various societies now focus on the husbandry, care, study and captive breeding of tarantulas, and other arachnids. They also typically produce journals or newsletters with articles and advice on these subjects. Examples would be:

- American Tarantula Society (ATS)
- British Tarantula Society (BTS)
- Deutsche Arachnologische Gesellschaft e.V.

Chapter- 6

Cetology

A researcher fires a biopsy dart at an orca. The dart will remove a small piece of the whale's skin and bounce harmlessly off the animal.

Cetology (from Greek κῆτος, *kētos*, "whale"; and -λογία, *-logia*) is the branch of marine mammal science that studies the approximately eighty species of whales, dolphins, and porpoise in the scientific order Cetacea.

Cetologists, or those who practice cetology, seek to understand and explain cetacean evolution, distribution, morphology, behavior, community dynamics, and other topics.

History

Observations about Cetacea have been recorded since at least classical times. Ancient Greek fishermen created an artificial notch on the dorsal fin of dolphins entangled in nets so that they could tell them apart years later.

Approximately 2,300 years ago, Aristotle carefully took notes on cetaceans while traveling on boats with fishermen in the Aegean Sea. In his book *Historia animalium* (History of animals), Aristotle was careful enough to distinguish between the baleen whales and toothed whales, a taxonomical separation still used today. He also described the Sperm Whale and the common dolphin, stating that they can live for at least twenty-five or thirty years. His achievement was remarkable for its time, because even today it is very difficult to estimate the life-span of advanced marine animals.

After Aristotle's death, much of the knowledge he had gained about cetaceans was lost, only to be re-discovered during the Renaissance.

Many of the medieval texts on cetaceans comes mainly from Scandinavia and Iceland, most come about around the mid-13th century.

One of the better known is *Speculum Regale*. In this text is described various species that lived around the island of Iceland. It mentions "orcs" that had dog-like teeth and would demonstrate the same kind of aggression towards other cetaceans as wild dogs would do to other terrestrial animals. The text even illustrated the hunting technique of Orcs, which are now called Orcas.

The *Speculum Regale* describes other cetaceans, including the Sperm Whale and Narwhal. Many times they were seen as terrible monsters, such as killers of men, and destroyers of ships. They even bore them odd names such as "Pig Whale", "Horse Whale", and "Red Whale".

But not all creatures described were said to be fierce. Some were seen to be good, such as whales that drove shoals of herring towards the shore. This was seen as very helpful to fisherman.

Many of the early studies were based on dead specimens and myth. The little information that was gathered was usual length, and a rough outer body anatomy. Because these animals live in water their entire lives, early scientists did not have the technology to go

study these animals further. It was not until the 16th century that things would begin to change. That cetaceans would be proved to be mammals rather than fish.

Aristotle, as said above, argued they were mammals. But Pliny the Elder stated that they were fish, and it was followed by many naturalists. However, Pierre Belon (1517–1575) and G. Rondelet (1507–1566) persisted on convincing they were mammals. They argued that the animals had lungs and a uterus, just like mammals. Not until 1758, when Swedish botanist Carolus Linnaeus (1707–1778) published the tenth edition of *Systema Naturae*, were they seen as mammals.

Only decades later, French zoologist and paleontologist Baron Georges Cuvier (1769–1832) described the animals as mammals without any hind legs. Skeletons were assembled and displayed in the first natural history museums, and on a closer look and comparisons with other extinct animal fossils led zoologists to conclude that cetaceans came from a family of ancient land mammals.

Between the 9th-20th century, much of our information on cetaceans came from whalers. Whalers were the most knowledgeable about the animals, but their information was regarding migration routes and outer anatomy, and only little information of behavior.

During the 1960s, people began studying the animals intensively, often in dedicated research institutes such as the Tethys Research Institute in Milan. This came from both concern about wild populations and also the capture of larger animals such as the Orca, and gaining popularity of dolphin shows in marine parks.

Studying cetaceans

Humpback Whales often have distinct markings that enable scientists to identify individuals.

Studying cetaceans presents numerous challenges. Cetaceans only spend 10% of their time on the surface, and all they do at the surface is breathe. There is very little behavior seen at the surface.

It is also impossible to find any signs that an animal has been in an area. Cetaceans do not leave tracks that can be followed, nor do they leave dung that can tell important information about their diet. Many times Cetology consists of waiting and paying close attention.

Cetologists use equipment including hydrophones to listen to calls of communicating animals, binoculars and other optical devices for scanning the horizon, cameras, notes, and a few other devices and tools.

An alternative method of studying cetaceans is through examination of dead carcasses that wash up on the shore. If properly collected and stored, these carcasses can provide important information that is difficult to obtain in field studies.

Identifying individuals

In recent decades, methods of identifying individual cetaceans have enabled accurate population counts and insights into the lifecycles and social structures of various species.

One such successful system is photo-identification. This system was popularized by Michael Bigg, a pioneer in modern orca (killer whale) research. During the mid 1970s, Bigg and Graeme Ellis photographed local orcas in the British Columbian seas. After examining the photos, they realized they could recognize certain individual whales by looking at the shape and condition of the dorsal fin, and also the shape of the saddle patch. These are as unique as a human fingerprint; no one animal's looks exactly like another's. After they could recognize certain individuals, they found that the animals travel in stable groups called pods. Researchers use photo identification to identify specific individuals and pods.

The photographic system has also worked well in humpback whale studies. Researchers use the color of the pectoral fins and color of the fluke to identify individuals. Scars from orca attacks found on the flukes of humpbacks are also used in identification.

Chapter- 7

Neuroethology

Echolocation in bats is one model system in neuroethology

Neuroethology (from Greek *νεῦρον* - *neuron* "nerve" and *ἦθος* - *ethos* "habit or custom") is the evolutionary and comparative approach to the study of animal behavior and its underlying mechanistic control by the nervous system. This interdisciplinary branch of neuroscience endeavors to understand how the central nervous system translates biologically relevant stimuli into natural behavior". For example, many bats are capable of echolocation which is used for prey capture and navigation. Their ultrasonic calls and auditory systems are highly specialized for this function. The auditory system of bats is often cited as an example for how acoustic properties of sounds can be converted into a sensory map of behaviorally relevant features of sounds . Neuroethologists hope to uncover general principles of the nervous system from the study of animals with exaggerated or specialized behaviors.

As its name implies, neuroethology is a multidisciplinary field composed of neurobiology (the study of the nervous system) and ethology (the study of behavior in natural conditions). A central theme of the field of neuroethology, delineating it from other branches of neuroscience, is this focus on natural behavior. Natural behaviors may be thought of as those behaviors generated through means of natural selection (i.e. finding mates, navigation, locomotion, predator avoidance) rather than behaviors in disease states, or behavioral tasks that are particular to the laboratory.

Philosophy

Neuroethology is an integrative approach to solving problems in animal behavior, drawing upon several disciplines. Often, neuroethologists choose to study animals that are “specialists” in a particular type of behavior the researcher wishes to study (i.e. honeybees and their social behavior, bat echolocation, owl sound localization). The idea

that an ideal animal exists for studying specific behaviors is based on Krogh's principle. The neuroethological approach stems from the idea that animals' nervous systems have evolved to address problems of sensing and acting in certain environmental niches. Central to the dogma of neuroethology, therefore, is the idea that nervous systems are best understood in the context of the problems they have evolved to solve.

The scope of neuroethological inquiry might be summarized by Jörg-Peter Ewert, a pioneer of neuroethology, when he considers the types of questions central to neuroethology in his 1980 introductory text to the field:

1. How are stimuli detected by an organism?
2. How are environmental stimuli in the external world represented in the nervous system?
3. How is information about a stimulus acquired, stored and recalled by the nervous system?
4. How is a behavioral pattern encoded by neural networks?
5. How is behavior coordinated and controlled by the nervous system?
6. How can the ontogenetic development of behavior be related to neural mechanisms?

Often central to addressing questions in neuroethology are comparative methodologies, drawing upon knowledge about related organisms' nervous systems, anatomies, life histories, behaviors and environmental niches. While it is not unusual for many types of neurobiology experiments to give rise to behavioral questions, many neuroethologists often begin their research programs by observing a species' behavior in its natural environment. Other approaches to understanding nervous systems include the systems identification approach, popular in engineering. The idea is to stimulate the system using a non-natural stimulus with certain properties. The system's response to the stimulus may be used to analyze the operation of the system. Such an approach is useful for linear systems, but the nervous system is notoriously nonlinear, and neuroethologists argue that such an approach is limited. This argument is supported by experiments in the auditory system. These experiments show that neural responses to complex sounds, like social calls, can not be predicted by the knowledge gained from studying the responses due to pure tones (one of the non-natural stimuli favored by auditory neurophysiologists). This is because of the non-linearity of the system.

Modern neuroethology is largely influenced by the research techniques used. Neural approaches are necessarily very diverse, as is evident through the variety of questions asked, measuring techniques used, relationships explored, and model systems employed. Techniques utilized since 1984 include the use of intracellular dyes, which make maps of identified neurons possible, and the use of brain slices, which bring vertebrate brains into better observation through intracellular electrodes (Hoyle 1984). Currently, other fields toward which neuroethology may be headed include computational neuroscience, molecular genetics, neuroendocrinology. The existing field of neural modeling may also expand into neuroethological terrain, due to its practical uses in robotics. In all this,

neuroethologists must use the right level of simplicity to effectively guide research towards accomplishing the goals of neuroethology.

Critics of neuroethology might consider it a branch of neuroscience concerned with 'animal trivia'. Though neuroethological subjects tend not to be traditional neurobiological model systems (i.e. *Drosophila*, *C. elegans*, or *Danio rerio*), neuroethological approaches emphasizing comparative methods have uncovered many concepts central to neuroscience as a whole, such as lateral inhibition, coincidence detection, and sensory maps. The discipline of neuroethology has also discovered and explained the only vertebrate behavior for which the entire neural circuit has been described: the electric fish jamming avoidance response. Beyond its conceptual contributions, neuroethology makes indirect contributions to advancing human health. By understanding simpler nervous systems, many clinicians have used concepts uncovered by neuroethology and other branches of neuroscience to develop treatments for devastating human diseases.

Historical origins

The field of neuroethology owes part of its existence to the establishment of ethology as a unique discipline within the discipline of Zoology. Although animal behavior had been studied since the time of Aristotle (384-342 BC), it was not until the early twentieth century that ethology finally became distinguished from natural science (a strictly descriptive field) and ecology. The main catalysts behind this new distinction were the research and writings of Konrad Lorenz and Niko Tinbergen.

Konrad Lorenz was born in Austria in 1903, and is widely known for his contribution of the theory of fixed action patterns (FAPs): endogenous, instinctive behaviors involving a complex sequence of movements that are triggered ("released") by a certain kind of stimulus. This sequence always proceeds to completion, even if the original stimulus is removed. It is also species-specific and performed by nearly all members. Lorenz constructed his famous "hydraulic model" to help illustrate this concept, as well as the concept of action specific energy, or drives.

Niko Tinbergen was born in the Netherlands in 1907 and worked closely with Lorenz in the development of the FAP theory; their studies focused on the egg retrieval response of nesting geese. Tinbergen performed extensive research on the releasing mechanisms of particular FAPs, and used the bill-pecking behavior of baby herring gulls as his model system. This led to the concept of the supernormal stimulus. Tinbergen is also well known for his four questions that he believed ethologists should be asking about any given animal behavior; among these is that of the mechanism of the behavior, on a physiological, neural and molecular level, and this question can be thought of in many regards as the keystone question in neuroethology. Tinbergen also emphasized the need for ethologists and neurophysiologists to work together in their studies, a unity that has become a reality in the field of neuroethology.

Unlike behaviorism, which studied animals' reactions to non-natural stimuli in artificial, laboratory conditions, ethology sought to categorize and analyze the natural behaviors of animals in a field setting. Similarly, neuroethology asks questions about the neural bases of *naturally occurring* behaviors, and seeks to mimic the natural context as much as possible in the laboratory.

Although the development of ethology as a distinct discipline was crucial to the advent of neuroethology, equally important was the development of a more comprehensive understanding of Neuroscience. Contributors to this new understanding were the Spanish Neuroanatomist, Ramon y Cajal, and physiologists Charles Sherrington, Edgar Adrian, Alan Hodgkin, and Andrew Huxley. Charles Sherrington, who was born in Great Britain in 1857, is famous for his work on the nerve synapse as the site of transmission of nerve impulses, and for his work on reflexes in the spinal cord. His research also led him to hypothesize that every muscular activation is coupled to an inhibition of the opposing muscle. He was awarded a Nobel Prize for his work in 1932 along with Lord Edgar Adria who made the first physiological recordings of neural activity from single nerve fibers.

Alan Hodgkin and Andrew Huxley (born 1914 and 1917, respectively, in Great Britain), are known for their collaborative effort to understand the production of action potentials in giant squid neurons. The pair also proposed the existence of ion channels to facilitate action potential initiation, and were awarded the Nobel Prize in 1963 for their efforts.

As a result of this pioneering research, many scientists then sought to connect the physiological aspects of the nervous and sensory systems to specific behaviors. These scientists – Karl von Frisch, Erich von Holst, and Theodore Bullock – are frequently referred to as the “fathers” of neuroethology. Neuroethology did not really come into its own, though, until the 1970s and 1980s, when new, sophisticated experimental methods allowed researchers such as Mark Konishi, Walter Heiligenberg, Jörg-Peter Ewert, and others to study the neural circuits underlying verifiable behavior.

Modern neuroethology

The International Society for Neuroethology (ISN) represents the present discipline of neuroethology, which was founded on the occasion of the NATO-Advanced Study Institute "Advances in Vertebrate Neuroethology" (August 13-24, 1981) organized by J.-P. Ewert, D.J. Ingle and R.R. Capranica, held at the University of Kassel in Hofgeismar, Germany (cf. report Trends in Neurosci. 5:141-143,1982). The first president of ISN was Theodore H. Bullock. The ISN has met every three years since its first meeting in Tokyo in 1986.

Its membership draws from many research programs around the world; many of its members are students and faculty members from medical schools and neurobiology departments from various universities. Modern advances in neurophysiology techniques have enabled more exacting approaches in an ever-increasing number of animal systems, as size limitations are being dramatically overcome. Survey of the most recent (2007) congress of the ISN meeting symposia topics gives some idea of the field’s breadth:

- Comparative aspects of spatial memory (rodents, birds, humans, bats)
- Influences of higher processing centers in active sensing (primates, owls, electric fish, rodents, frogs)
- Animal signaling plasticity over many time scales (electric fish, frogs, birds)
- Song production and learning in passerine birds
- Primate sociality
- Optimal function of sensory systems (flies, moths, frogs, fish)
- Neuronal complexity in behavior (insects, computational)
- Contributions of genes to behavior (Drosophila, honeybees, zebrafish)
- Eye and head movement (crustaceans, humans, robots)
- Hormonal actions in brain and behavior (rodents, primates, fish, frogs, and birds)
- Cognition in insects (honeybee)

Application to technology

Neuroethology can help create advancements in technology through an advanced understanding of animal behavior. Model systems were generalized from the study of simple and related animals to humans. For example the neuronal cortical space map discovered in bats, a specialized champion of hearing and navigating, elucidated the concept of a computational space map. In addition, the discovery of the space map in the barn owl led to the first neuronal example of the Jeffress model. This understanding is translatable to understanding spatial localization in humans, a mammalian relative of the bat. Today, knowledge learned from neuroethology are being applied in new technologies. For example, Randall Beer and his colleagues used algorithms learned from insect walking behavior to create robots designed to walk on uneven surfaces (Beer et al.). . Neuroethology and technology contribute to one another bidirectionally.

Neuroethologists seek to understand the neural basis of a behavior as it would occur in an animal's natural environment but the techniques for neurophysiological analysis are lab-based, and cannot be performed in the field setting. This dichotomy between field and lab studies poses a challenge for neuroethology. From the neurophysiology perspective, experiments must be designed for controls and objective rigor, which contrasts with the ethology perspective—that the experiment be applicable to the animal's natural condition, which is uncontrolled, or subject to the dynamics of the environment. An early example of this is when Walter Rudolf Hess developed focal brain stimulation technique to examine a cat's brain controls of vegetative functions in addition to other behaviors. Even though this was a breakthrough in technological abilities and technique, it was not used by many neuroethologists originally because it compromised a cat's natural state, and, therefore, in their minds, devalued the experiments' relevance to real situations.

When intellectual obstacles like this were overcome, it led to a golden age of neuroethology, by focusing on simple and robust forms of behavior, and by applying modern neurobiological methods to explore the entire chain of sensory and neural mechanisms underlying these behaviors (Zupanc 2004). New technology allows neuroethologists to attach electrodes to even very sensitive parts of an animal such as its brain while it interacts with its environment. The founders of neuroethology ushered this

understanding and incorporated technology and creative experimental design. Since then even indirect technological advancements such as battery-powered and waterproofed instruments have allowed neuroethologists to mimic natural conditions in the lab while they study behaviors objectively. In addition, the electronics required for amplifying neural signals and for transmitting them over a certain distance have enabled neuroscientists to record from behaving animals performing activities in naturalistic environments. Emerging technologies can complement neuroethology, augmenting the feasibility of this valuable perspective of natural neurophysiology.

Another challenge, and perhaps part of the beauty of neuroethology, is experimental design. The value of neuroethological criteria speak to the reliability of these experiments, because these discoveries represent behavior in the environments in which they evolved. Neuroethologists foresee future advancements through using new technologies and techniques, such as computational neuroscience, neuroendocrinology, and molecular genetics that mimic natural environments.

Case studies

Jamming avoidance response

In 1963, two scientists, Akira Watanabe and Kimihisa Takeda, discovered the behavior of the jamming avoidance response in the knifefish *Eigenmannia* sp. In collaboration with T.H. Bullock and colleagues, the behavior was further developed. Finally, the work of W. Heiligenberg expanded it into a full neuroethology study by examining the series of neural connections that led to the behavior. *Eigenmannia* is a weakly electric fish that can self-generate electric discharges through electrocytes in its tail. Furthermore, it has the ability to electrolocate by analyzing the perturbations in its electric field. However when the frequency of a neighboring fish's current is very close (less than 20 Hz difference) to that of its own, the fish will avoid having their signals interfere through a behavior known as Jamming Avoidance Response. If the neighbor's frequency is higher than the fish's discharge frequency, the fish will lower its frequency, and vice versa. The sign of the frequency difference is determined by analyzing the "beat" pattern of the incoming interference which consists of the combination of the two fish's discharge patterns.

Neuroethologists performed several experiments under *Eigenmannia*'s natural conditions to study how it determined the sign of the frequency difference. They manipulated the fish's discharge by injecting it with curare which prevented its natural electric organ from discharging. Then, an electrode was placed in its mouth and another was placed at the tip of its tail. Likewise, the neighboring fish's electric field was mimicked using another set of electrodes. This experiment allowed neuroethologists to manipulate different discharge frequencies and observe the fish's behavior. From the results, they were able to conclude that the electric field frequency, rather than an internal frequency measure, was used as a reference. This experiment is significant in that not only does it reveal a crucial neural mechanism underlying the behavior but also demonstrates the value neuroethologists place on studying animals in their natural habitats.

Feature analysis in toad vision

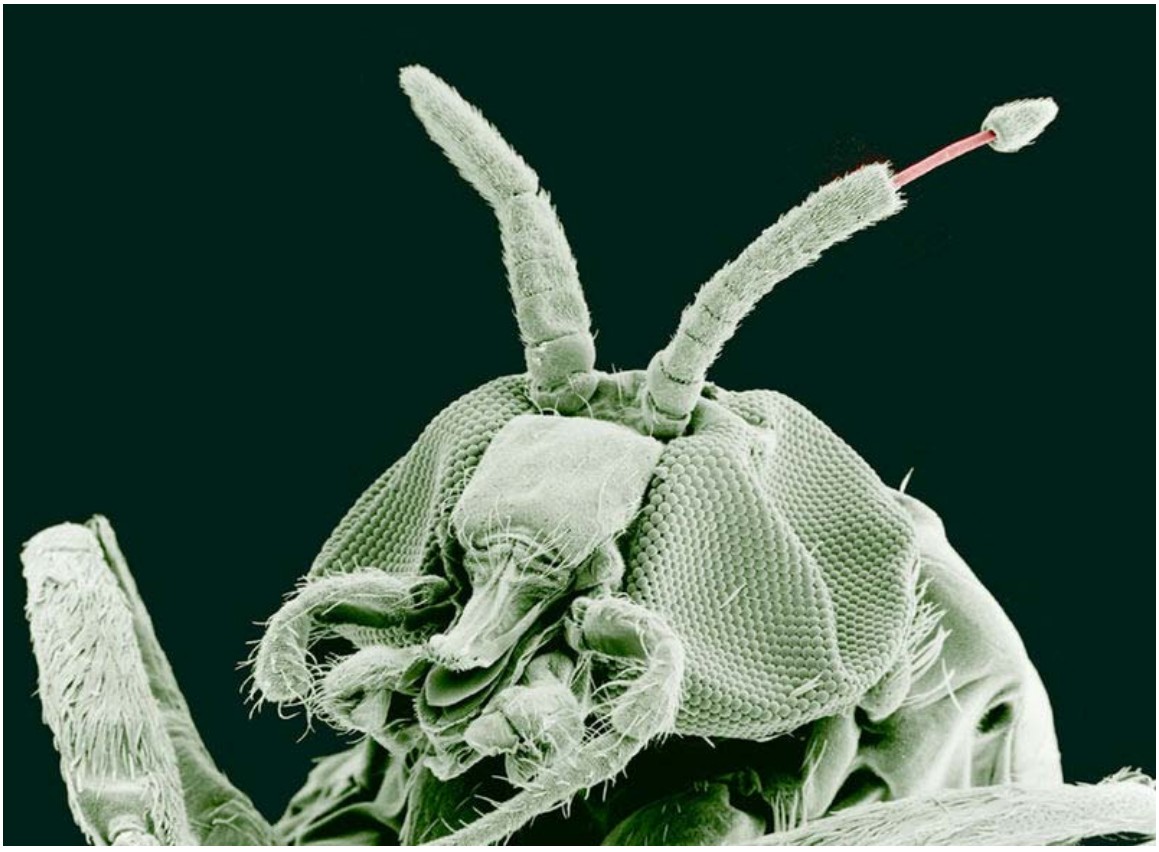
The recognition of prey and predators in the toad was first studied in depth by Jörg-Peter Ewert. He began by observing the natural prey-catching behavior of the common toad (*Bufo bufo*) and concluded that the animal followed a sequence that consisted of stalking, binocular fixation, snapping, swallowing and mouth-wiping. However, initially, the toad's actions were dependent on specific features of the sensory stimulus: whether it demonstrated worm or anti-worm configurations. It was observed that the worm configuration, which signaled prey, was initiated by movement along the object's long axis, whereas anti-worm configuration, which signaled predator, was due to movement along the short axis (Zupanc 2004).

Ewert and coworkers adopted a variety of methods to study the predator versus prey behavior response. They conducted recording experiments where they inserted electrodes into the brain, while the toad was presented with worm or anti-worm stimuli. This technique was repeated at different levels of the visual system and also allowed feature detectors to be identified. In focus was the discovery of prey-selective neurons in the optic tectum, whose axons could be traced towards the snapping pattern generating cells in the hypoglossal nucleus. The discharge patterns of prey-selective tectal neurons in response to prey objects – in freely moving toads – „predicted" prey-catching reactions such as snapping. Another approach, called stimulation experiment, was carried out in freely moving toads. Focal electrical stimuli were applied to different regions of the brain, and the toad's response was observed. When the thalamic-pretectal region was stimulated, the toad exhibited escape responses, but when the tectum was stimulated in an area close to prey-selective neurons, the toad engaged in prey catching behavior (Carew 2000). Furthermore, neuroanatomical experiments were carried out where the toad's thalamic-pretectal/tectal connection was lesioned and the resulting deficit noted: the prey-selective properties were abolished both in the responses of prey-selective neurons and in the prey catching behavior. These and other experiments suggest that prey selectivity results from pretecto-tectal influences.

Ewert and coworkers showed in toads that there are stimulus-response mediating pathways that translate perception (of visual sign stimuli) into action (adequate behavioral responses). In addition there are modulatory loops that initiate, modify or specify this mediation (Ewert 2004). Regarding the latter, for example, the telencephalic caudal ventral striatum is involved in a loop gating the stimulus-response mediation in a manner of directed attention. The telencephalic ventral medial pallium („primordium hippocampi"), however, is involved in loops that either modify prey-selection due to associative learning or specify prey-selection due to non-associative learning, respectively.

Chapter- 8

Parasitology



Adult black fly (*Simulium yahense*) with (*Onchocerca volvulus*) emerging from the insect's antenna. The parasite is responsible for the disease known as river blindness in Africa. Sample was chemically fixed and critical point dried, then observed using conventional scanning electron microscopy. Magnified 100×.

Parasitology is the study of parasites, their hosts, and the relationship between them. As a biological discipline, the scope of parasitology is not determined by the organism or environment in question, but by their way of life. This means it forms a synthesis of other disciplines, and draws on techniques from fields such as cell biology, bioinformatics, biochemistry, molecular biology, immunology, genetics, evolution and ecology.

Fields

The study of these diverse organisms means that the subject is often broken up into simpler, more focused units, which use common techniques, even if they are not studying the same organisms or diseases. Much research in parasitology falls somewhere between two or more of these definitions. In general, the study of prokaryotes fall under the field of bacteriology rather than parasitology.

Medical parasitology

One of the largest fields in parasitology, medical parasitology is the subject which deals with the parasites that infect man, the diseases caused by them, clinical piture and the response generated by man against them. It's also concerned with the various methods of their diagnosis, treatment and finally their prevention & control. A parasite is an organism that live on or within another organism called the host . These include organisms such as:

- *Plasmodium* spp., the protozoan parasite which causes malaria. The four species of malaria parasites infective to humans are *Plasmodium falciparum*,*Plasmodium malariae*, *Plasmodium vivax* & *Plasmodium ovale*.
- *Leishmania donovani*, the unicellular organism which causes leishmaniasis
- multicellular organisms such as *Schistosoma* spp., *Wuchereria bancrofti* and *Necator americanus*

Medical parasitology can involve drug development, epidemiological studies and study of zoonoses.

Veterinary parasitology

The study of parasites that cause economic losses in agriculture or aquaculture operations, or which infect companion animals. Examples of species studied are:

- *Lucilia sericata*, a blowfly, which lays eggs on the skins of farm animals. The maggots hatch and burrow into the flesh, distressing the animal and causing economic loss to the farmer
- *Otodectes cynotis*, the cat ear mite, responsible for Canker.
- *Gyrodactylus salaris*, a monogenean parasite of salmon, which can wipe out populations which are not resistant.

Structural parasitology

This is the study of structures of proteins from parasites. Determination of parasitic protein structures may help to better understand how these proteins function differently from homologous proteins in humans. In addition, protein structures may inform the process of drug discovery.

Quantitative parasitology

Parasites exhibit an aggregated distribution among host individuals, thus the majority of parasites live in the minority of hosts. This feature forces parasitologists to use advanced biostatistical methodologies.

Parasite ecology

Parasites can provide information about host population ecology. In fisheries biology, for example, parasite communities can be used to distinguish distinct populations of the same fish species co-inhabiting a region. Additionally, parasites possess a variety of specialized traits and life-history strategies that enable them to colonize hosts. Understanding these aspects of parasite ecology, of interest in their own right, can illuminate parasite-avoidance strategies employed by hosts

Conservation biology of parasites

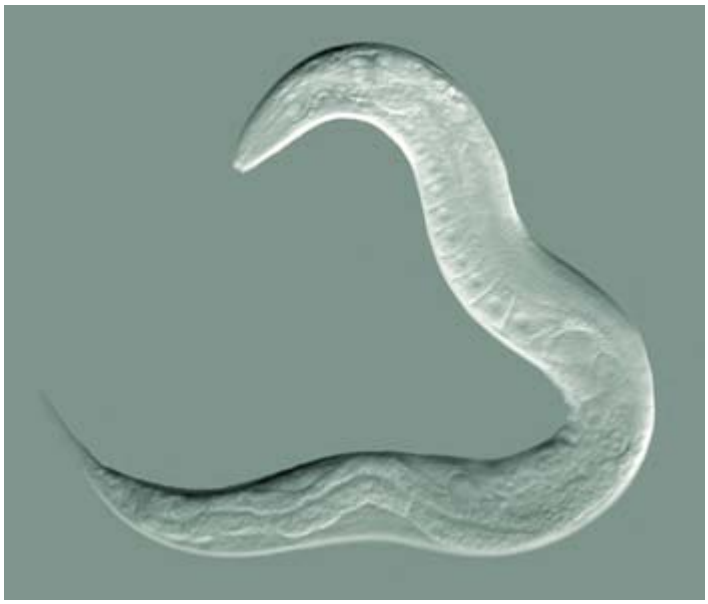
Conservation biology is concerned with the protection and preservation of vulnerable species, including parasites. A large proportion of parasite species are threatened by extinction, partly due to efforts to eradicate parasites which infect humans or domestic animals, or damage human economy, but also caused by the decline or fragmentation of host populations and the extinction of host species.

Taxonomy and phylogenetics

The huge diversity between parasitic organisms creates a challenge for biologists who wish to describe and catalogue them. Recent developments in using DNA to identify separate species and to investigate the relationship between groups at various taxonomic scales has been enormously useful to parasitologists, as many parasites are highly degenerate, disguising relationships between species.

Chapter- 9

Nematology



Nematology is the scientific discipline concerned with the study of nematodes, or roundworms. Although nematological investigation dates back to the days of Aristotle or even earlier, nematology as an independent discipline has its recognizable beginnings in the mid to late 19th century.

History of Nematology: Pre-1850

Nematology research, like most fields of science, has its foundations in observations and the recording of these observations. The earliest written account of a nematode "sighting," as it were, may be found in the Pentateuch of the Old Testament in the Bible, in the Fourth Book of Moses called Numbers: "And the Lord sent fiery serpents among the people, and they bit the people; and much people of Israel died". Although no empirical data exists to test the hypothesis, many nematologists assume and circumstantial evidence suggests the "fiery serpents" to be the Guinea worm, *Dracunculus medinensis*, as this nematode is known to inhabit the region near the Red Sea.

Before 1750, a large number of nematode observations were recorded, many by the notable great minds of ancient civilization. Hippocrates (ca. 420 B.C.), Aristotle (ca. 350 B.C.), Celsus (ca 10 B.C.), Galen (ca. 180 A.D.) and Redi (1684) all described nematodes parasitizing humans or other large animals and birds. Borellus (1653) was the first to observe and describe a free-living nematode, which he dubbed the "vinegar eel;" and Tyson (1683) used a crude microscope to describe the rough anatomy of the human intestinal roundworm, *Ascaris lumbricoides*.

Other well-known microscopists spent time observing and describing free-living and animal-parasitic nematodes: Hooke (1683), Leeuwenhoek (1722), Needham (1743), and Spallanzani (1769) are among these. Observations and descriptions of plant parasitic nematodes, which were less conspicuous to ancient scientists, didn't receive as much or as early attention as did animal parasites. The earliest allusion to a plant parasitic nematode is, however, preserved in famous writ. "Sowed cockle, reap'd no corn," a line by William Shakespeare penned in 1594 in *Love Labour's Lost', Act IV, Scene 3, most certainly has reference to blighted wheat caused by the plant parasite,* Anguina tritici.

Needham (1743) solved the "riddle of cockle" when he crushed one of the diseased wheat grains and observed "Aquatic Animals…denominated Worms, Eels, or Serpents, which they very much resemble." It is likely that few or no other recorded observations of plant parasitic nematodes or their effects are to be found in ancient literature.

From 1750 to the early 1900's, nematology research continued to be descriptive and taxonomic, focusing primarily on free-living nematodes and plant and animal parasites. During this period a number of productive researchers contributed to the field of nematology in the United States and abroad. Beginning with Needham and continuing to Cobb, nematologists compiled and continuously revised a broad descriptive morphological taxonomy of nematodes.

History of Nematology: 1850 to the Present

Kuhn (1874) is thought to be the first to use soil fumigation to control nematodes, applying carbon disulfide treatments in sugar beet fields in Germany. In Europe from 1870 to 1910, nematological research focused heavily on controlling the sugar beet nematode as sugar beet production became an important economy during this time in the Old World.

Although 18th and 19th century scientists yielded a considerable amount of important fundamental and applied knowledge about nematode biology, nematology research really began to advance in quality and quantity near the turn of the 20th century. In 1918, the first permanent nematology field station was constructed in the U.S. Post Office in Salt Lake City, Utah under the direction of Harry B. Shaw, after scientists observed the sugar beet nematode in a field south of the city. In this same year, Nathan Cobb (1918) published his Contributions to a Science of Nematology and his lab manual "Estimating the Nema Population of Soil." These two publications provide definitive resources for many methods and apparatus used in nematology even to this day.

Of Cobb's far-reaching influence on nematology research, Jenkins and Taylor write:

Although many workers have played important roles in development of plant nematology, none have had a greater impact, particularly in the United States, than N.A. Cobb. In 1913 Cobb published his first paper on nematology in the United States. From [1913] to 1932 he was the undisputed leader in [nematology] in this country. Through his efforts the widely renowned [USDA] nematology research program was initiated and developed. Many of his students and colleagues developed into the leaders in plant nematology in the 1930's, 1940's, and 1950's. In addition, during his productive career he contributed major discoveries in the areas of nematode taxonomy, morphology, and in methodology. Many of his techniques are still unsurpassed!

Perhaps no one person has had as favorable an impact on the field of nematology as has Nathan Augustus Cobb.

From 1900-1925 various state-run agricultural experimental stations investigated important problems relating to agro-economy, though few stations devoted much attention to plant-parasitic nematodes. Accounts of the history of nematology (the few that exist) mention three major events occurring between 1926 and 1950 that affected the relative importance of nematodes in the eyes of farmers, legislators and the U.S. public in general. These same events had profound worldwide effects on the course of nematology research over the next fifty to seventy-five years

First, the discovery of the golden nematode in the potato fields of Long Island led to a trip by U.S. quarantine officials to the potato fields of Europe, where the devastating effects of this parasite had been known for many years. This excursion allayed all skepticism about the seriousness of this agricultural pest. Second, the introduction of the soil fumigants, D-D and EDB made available for the first time nematicides that could be used effectively and practically on a field scale. Third, the development of nematode-resistant crop cultivars brought substantial government funding to applied nematology research.

These events contributed to a shift from broad taxonomy-based nematology research to deep, yet focused investigations of plant parasitic nematodes, especially the control of agricultural pests. From the early 1930's until recently, the bulk of researchers studying nematodes have been plant pathologists by training. Consequently, nematological research leaned heavily toward answering plant pathological and agro-economical questions for the last three-quarters of the 20th century.

Nematological Societies and Federations

Afro-Asian Society of Nematologists (AASN)

Australian Association of Nematologists (AAN)

Brazilian Nematological Society (Sociedade Brasileira de Nematologia) (SBN)

Chinese Society of Plant Nematologists (CSPN)

Egyptian Society of Agricultural Nematology (ESAN)

- European Society of Nematologists

International Federation of Nematology Societies (IFNS)

Italian Society of Nematologists (Societa Italiana di Nematologia) (SIN)

Japanese Nematological Society (JNS)

Nematological Society of India (NSI)

Nematological Society of Southern Africa (Nematologiese Vereniging van Suidelike Afrika) (NSSA)

Organization of Nematologists of Tropical America (ONTA)

Pakistan Society of Nematologists (PSN)

Russian Society of Nematologists (RSN)

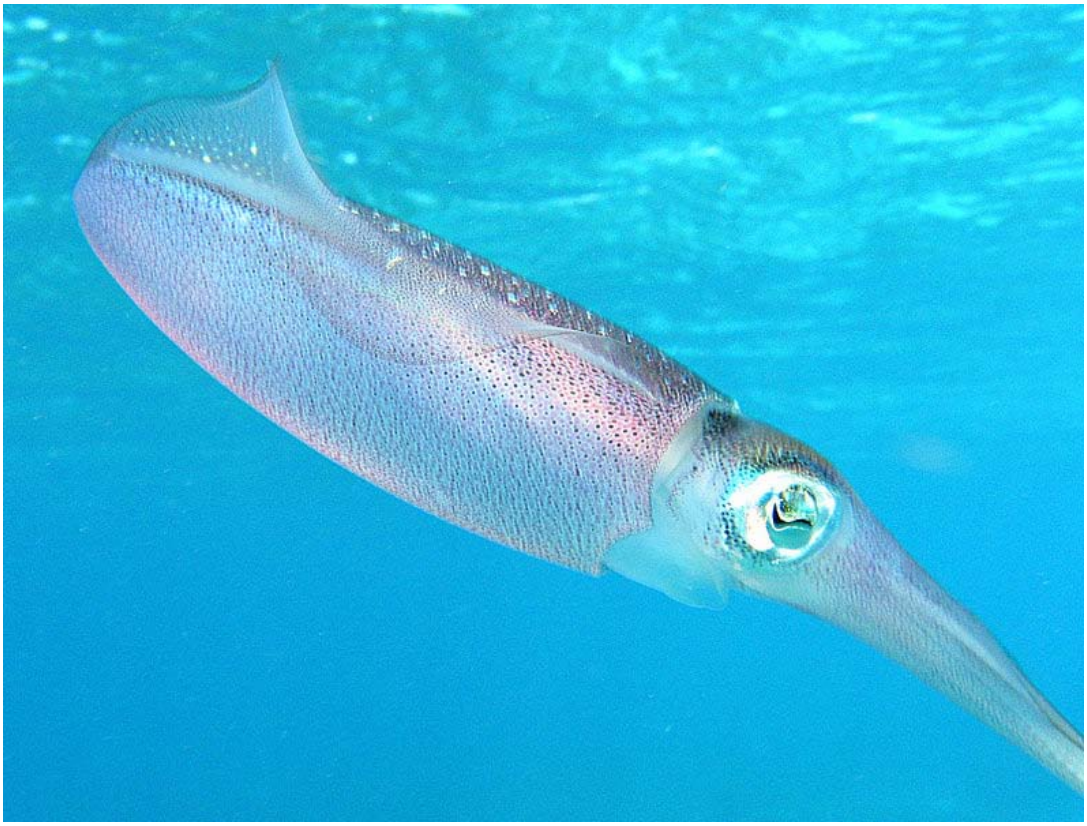
Society of Nematologists (SON)

Contributions of Nematology to Other Sciences

Nematologists in the 1800s also contributed to other scientific fields in important ways. Butschli (1875) first observed the formation of polar bodies by nuclear subdivision in a nematode, Beneden (1883) was studying *Ascaris megalocephala* when he discovered the separation of halves of each of the chromosomes from the two parents and the mechanism of Mendelian heredity, and Boveri (1893) showed evidence for continuity of the germ plasm and that the soma may be regarded as a by-product without influence upon heredity.

Chapter- 10

Malacology



Teuthology, a branch of malacology, deals with the study of cephalopods, such as the giant squid pictured

Malacology is the branch of invertebrate zoology which deals with the study of the Mollusca (mollusks or molluscs), the second-largest phylum of animals in terms of described species after the arthropods. Mollusks include snails and slugs, clams, octopus and squid, and numerous other kinds, many (but by no means all) of which have shells. One division of malacology, conchology, is devoted to the study of mollusk shells.

Fields within malacological research include taxonomy, ecology and evolution. Applied malacology studies medical, veterinary, and agricultural applications, for example mollusks as vectors of disease, as in schistosomiasis.

Archaeology employs malacology to understand the evolution of the climate, the biota of the area, and the usage of the site.

In 1681, Filippo Bonanni wrote the first book ever published that was solely about seashells. The book was entitled: *Ricreatione dell' occhio e dela mente nell oservation' delle Chiociolle, proposta a' curiosi delle opere della natura, &c.*. In 1868, the German Malacological Society was founded.

Malacologists

Those who study malacology are known as malacologists.

Societies

- American Malacological Society
- Association of Polish Malacologists (Stowarzyszenie Malakologów Polskich)
- Belgian Malacological Society (Société Belge de Malacologie) - French speaking
- Belgian Society for Conchology (Belgische Vereniging voor Conchyliologie) - Dutch speaking
- Conchological Society of Great Britain and Ireland
- Conchologists of America
- Dutch Malacological Society (Nederlandse Malacologische Vereniging)
- Estonian Malacological Society (Eesti Malakoloogia Ühing)
- European Quaternary Malacologists
- Freshwater Mollusk Conservation Society
- German Malacological Society (Deutsche Malakozoologische Gesellschaft)
- Italian Malacological Society (Società Italiana di Malacologia)
- Malacological Society of Australasia
- Malacological Society of London
- Malacological Society of the Philippines, Inc.
- Spanish Malacological Society (Sociedad Española de Malacología)
- Western Society of Malacologists

Journals

Journals within the field of malacology include:

- *American Malacological Bulletin*
- *Basteria*
- *Festivus*
- *Fish & Shellfish Immunology*
- *Folia Malacologica*
- *Heldia*
- *Johnsonia*
- *Journal of Conchology*

- *Journal of Medical and Applied Malacology*
- *Journal of Molluscan Studies*
- *Malacologia*
- *Malacologica Bohemoslovaca*
- *Malacological Review*
- *Mollusca*
- *Molluscan Research* - impact factor: 0.606 (2007)
- *Strombus*
- *Tentacle* - The Newsletter of the Mollusc Specialist Group of the Species Survival Commission of the International Union for Conservation of Nature.
- *The Nautilus* - since 1886 published by Bailey-Matthews Shell Museum. First two volumes were published under name *The Conchologists' Exchange*. Impact factor: 0.500 (2009)
- *The Veliger* - impact factor: 0.606 (2003)
- *Venus (Japanese Journal of Malacology)*
- *Vita Marina*

Museums

- Royal Belgian Institute of Natural Sciences, Brussels: with a collection of more than 9 million shells (mainly from the collection of Philippe Dautzenberg), it belongs to the three largest collections in the world.
- Bailey-Matthews Shell Museum
- Cau del Cargol Shell Museum
- Rinay

Chapter- 11

Herpetology and Paleozoology

Herpetology

Herpetology is the branch of zoology concerned with the study of amphibians (including frogs, toads, salamanders, newts, and gymnophionae) and reptiles (including snakes, lizards, amphisbaenids, turtles, terrapins, tortoises, crocodilians, and the tuataras). Batrachology is a further subdiscipline of herpetology concerned with the study of amphibians alone.

Herpetology is concerned with poikilothermic, ectothermic tetrapods. "Herps" (or sometimes "herptiles" or "herpetofauna") exclude fish. However, it is not uncommon for herpetological and ichthyological scientific societies to "team up", publishing joint journals and holding conferences in order to foster the exchange of ideas between the

fields. One of the most prestigious organizations, the American Society of Ichthyologists and Herpetologists, is an example of this. Many herpetological societies exist today, having been formed to promote interest in reptiles and amphibians both captive and wild.

Herpetology offers benefits to humanity in the study of the role of amphibians and reptiles in global ecology, especially because amphibians are often very sensitive to environmental changes, offering a visible warning to humans that significant changes are taking place. Some toxins and venoms produced by reptiles and amphibians are useful in human medicine. Currently, some snake venom has been used to create anti-coagulants that work to treat stroke victims and heart attack cases.

The word "herpetology" is from Greek: ἑρπήτόν, *herpeton*, "creeping animal" and -λογία, -*logia*. People with an avid interest in herpetology and who keep different reptiles or amphibians often refer to themselves as "herpers".

Careers

There are many careers in the field of herpetology. These include, but are not limited to, field research, public and private breeding, zoological staff or curating, museum staff or curating and college teaching.

Those wishing to pursue a career in herpetology must have a strong science and math background. Few universities offer this program, and thus it is a highly competitive field.

In modern academic science, it is rare for individuals to consider themselves a herpetologist first and foremost. Most individuals focus on a particular field such as ecology, evolution, taxonomy, physiology, or molecular biology, and within that field ask questions pertaining to or best answered by examining reptiles and amphibians. For example, an evolutionary biologist who is also a herpetologist may choose to work on how warning coloration evolved in coral snakes.

Paleozoology

Paleozoology, also spelled as **palaeozoology** (Greek: παλαιόν, *paleon* "old" and ζῷον, *zoon* "animal"), is the branch of paleontology or paleobiology dealing with the recovery and identification of multicellular animal remains from geological (or even archeological) contexts, and the use of these fossils in the reconstruction of prehistoric environments and ancient ecosystems.

Definitive, macroscopic remains of these metazoans are found in the fossil record from the Ediacaran period of the Neoproterozoic era onwards, although they do not become common until the Late Devonian period in the latter half of the Paleozoic era.

Perhaps the best known macrofossils group is the dinosaurs. Other popularly known animal-derived macrofossils include trilobites, crustaceans, echinoderms, brachiopods, mollusks, bony fishes, sharks, Vertebrate teeth, and shells of numerous invertebrate groups. This is because hard organic parts, such as bones, teeth, and shells resist decay, and are the most commonly preserved and found animal fossils. Exclusively soft-bodied animals -- such as jellyfish, flatworms, nematodes, and insects -- are consequently rarely fossilized, as these groups do not produce hard organic parts.