Avian Taxonomy and evolution

INTRODUCTION

- **9000 bird species, 24 orders and 170 families**
- Second most diverse vertebrate class (second to fish).

Birds, of all animals, offer the most favorable combination of attributes for scientific study. They are:
- numerous,
- diverse
- easily observed in the field
- many also adapt easily to experimentation in the laboratory.
What are birds?

Compared to the other vertebrate classes, birds form a homogeneous and distinct group characterized by:

1. **Feathers**

2. **Homeothermy** – able to physiologically regulate the internal body temperature

3. **Laying of eggs**

4. **Lack of teeth** – posses an epidermal covered bony beak.

5. **Pneumatic (air filled) bones** – hollow bones, i) the skull (nasal and tympanic air sac origin) ii) the humerus, clavicle, keel (sternum), the pelvic girdle, lumbar and sacral vertebrate (other respiratory system air sacs);
6. **Adaptations for flight** (about 123 species are flightless)

- lightness (due to 3, 4 and 5 above)
- Have feathers for flight
- streamlined
- centralization of weight
- efficient metabolism
  - Among vertebrates has higher body temperature therefore high rate of impulse generation therefore high muscle activity (see illustration)
  - Highly efficient unidirectional respiratory system with air sacs
  - Higher heart mass
- high visual acuity
- highly developed motor part of the brain (motor cortex)
Weight range from 2g (humming bird)
to 150kg (Ostrich)
Species definition

1. Biological species
   - A species is a group of individuals that can interbreed naturally to produce reproductively viable offspring.

2. Phylogenetic species
   - Since in some cases, interbreeding may be historical (ancestral), a phylogenetic species is one whose individuals will, in addition to being able to interbreed, have the closest evolutionary relationship.

Definition

A species is a group of individuals that can interbreed naturally to produce reproductively viable offspring and have the closest evolutionary relationship.
How then do species stay separated to maintain species integrity?

- They do so by being reproductively isolated either
  - behaviourally (different sexual behaviour)
  - genetically (infertile offspring)
  - anatomically (size, genitalia anatomy etc)
Taxonomy

- This is the classification and naming of organisms.

- 16th century
  - A system of classification was used based on birds' behavior: swimming, flying (fast or slow), catching prey with talons, etc.

- 17th Century
  - Classified birds on the basis of both general anatomy and behavior.
  - These classifications did not work because they were too simplistic and had little to do with real relationships.

- 18th Century
  - 1753 Carl Linneaus published Systema Naturae which set down a binomial system of classification for all organisms (based on morphology (comparative anatomy)).
  - Called binomial nomenclature
1. Five kingdom classification

Kingdoms:

- Monera (Archebacteria, Eubacteria) prokaryotes
- Protista (eukaryotes) – Protozoa, algae, molds; may be uni or multicellular (but with no specialised cells)
- Fungi (eukaryotes)
- Plantae (eukaryotes)
- Animalia (eukaryotes)
E.g the case of the ostrich
Kingdom Animalia

Phylum Chordata

- Subphylum Vertebrata

Class Aves

- Subclass Archeornithes: Archeopteryx (extinct)
- Subclass Neornithes: all other birds

Superorder

- Paleognathae – ratites and tinamous
- Neognathae – all other birds

Order -iformes

Family -idae

Subfamily -inae

(Tribe -ini)

Genus

Species

Subspecies, races, etc.
e.g. The ostrich

Order - Struthioniformes
Family - Struthionidae

Genus - camelus

Species - *Struthio camelus*

Subspecies
- *Struthio camelus massaicus* – maasai ostrich
- *Struthio camelus molybdophanes* – somali ostrich
Avian classification at the order level

1. **Passeriformes** – songbirds, makes 60% of bird spps. Most have complex song and relatively large brains – warblers, shrikes, birds of paradise, sunbirds, sparrows, weavers, bulbuls

2. **Tinamiformes** – tinamous

3. **Galliformes** – turkey, pheasants, chicken, quail

4. **Anseriformes** – ducks, geese, swans

5. **Piciformes** - woodpeckers

6. **Trogoniformes** - trogons

7. **Coraciiformes** – kingfishers, hornbills

8. **Colliformes** - mousebirds

9. **Cuculiformes** - cuckoos

10. **Psittaciformes** - parrots
11. Apodiformes – swifts, humming birds
12. Musophagiformes - turacos
13. Strigiformes - owls
14. Columbiformes – pigeons, doves
15. Gruiformes – cranes, bustards
16. Ciconiiformes – egrets, herons, ibis?, hamerkop
17. Caprimulgiformes – nightjars
18. Charadriiformes – puffins, plovers
19. Falconiformes – eagles, falcons, kestrels, hawks
20. Gaviiformes – loons, divers
21. Pelecaniformes – pelicans, darters, cormorants, ibis?
22. Phoenocopteriformes – flamingoes
24. Struthioniformes – ostriches, rheas, emu, kiwis
Evolution -

Definition - Descent with modification from a common ancestor

Two alternative theories for the origin of life on earth

- 1. Special creation theory
- 2. Evolution theory (Theory of descent with modification from a common ancestor)

1. Special creation theory (Genesis 1:1-27) postulates
   - i) That life originated as it is found today (unchanged, immutable)
   - ii) That all organisms were created independent of one another
   - iii) That the age of earth is young, 6015 years old (John Ussher, Bishop of Armagh)
On the contrary

Theory of Descent with modification from a common ancestor (Darwin, 1858) postulates that

• i) Life originated in a different form from that found today, organisms are not immutable

• ii) Organisms originated by descent from one common ancestor

• iii) That the age of earth is considerably old
Evidence for Evolution

Question (postulation) 1. Are organisms immutable?

- Evidence from
  Fossil evidence
Fossil evidence

- Fossils – Hard mineralised (petrified) body parts (usually hard tissues, bones, teeth, shells) of past living organisms found embedded in rock layers
Fossils provide evidence of extinctions

- **Mastodon** fossils excavated in Paris; **Irish Elk**
- first 23 extinct species identified and listed (Georges Cuvier, 1818)
Question (Postulation) 2. Did organisms originate independently?

- **Evidence**

- **Homology** – Structures that have different form and function but have the same basic anatomical design

![Diagram of homologous structures](image-url)
Question 3. Is the earth young (6000 years)?

Evidence

- Rock and fossil relative dating using radiometry (mass spectrometry)

- Radioisotopes measuring parent/daughter ratios have given the age of the earth at 4.6 billion years.

- Unit measure is half-life of parent isotope, the time it takes for 50% parent isotope to convert to daughter isotope

- Isotopes are not affected by any environmental factors; moisture, heat, light etc therefore have constant decay rate

Common isotopes

- $\text{K}^{40} - \text{Argon}^{40}$ (1/2 life 1.3 billion years)
- $\text{Uranium}^{245} - \text{Lead}^{207}$ (71.3 million years)
Conclusion

1. Species change over time, they are mutable [extinct species no longer exist; earlier species composition was different from what we see today]
2. Species have a common ancestry
3. The age of the earth is estimated at 4.6 billion

The evidence above supports the Theory of Evolution (Descent with modification from a common ancestor)
The mechanism by which evolution takes place is **natural selection**
Mechanism of natural selection
The mechanism as stipulate by Darwin postulates that

1. Individuals in a population are **variable (trait)**

2. This **variation is inherited** from parents to offspring

3. In every generation, there are **differences in survival and reproduction**

4. This **difference is not random**, individuals with **favorable variations** survive to reproduce or reproduce more **successfully** than other individuals in the population **leaving more offspring** and increasing the frequency of the variation from generation to generation – this is evolution **by natural selection**

**Nb** that all these steps must be present for natural selection to occur
Variable traits
Traits not variable
Micro- and macroevolution

- **Microevolution**
  - Small changes resulting from genetic adaptation (genetic landscape) within a species.

- **Macroevolution**
  - Evolutionary change taking place above the level of a species. This results in the formation of a new species.
How do avian species form?

- Theories

1. Dispersal and colonisation of islands
2. Vicariance
Dispersal and colonization

- Some populations disperse and colonize of islands or isolated habitats.

- Populations invade from mainland, or move from island to island as in the Galapagos.

- On each **isolated** site they evolve adaptations to local conditions, so they split and differentiate in their genes in different pathways until they are distinct species. In this model the birds disperse from one area to another.
2. Vicariance theory

- **Vicariance** is a process by which the geographical range of an individual species is split by the formation of a physical barrier to dispersal (and therefore a barrier to gene flow)

- E.g. separation of Godwanaland beginning 200m years ago into Africa, South America, Indian subcontinent, Australia and Antarctica (explains the splitting of ratites)
Evolutionary classification

- This uses comparative analysis among species to work out species relationships (i.e. evolutionary or historical relationships)

- Conventionally referred to as systematics.
Cladistics

- Cladistics is a particular method of working out evolutionary relationships among organisms.

- Cladistics is now accepted as the best method available for phylogenetic (evolutionary relationships) analysis.
In cladistics;

1. **Members of a group (lineage)** share a common evolutionary history, and are “closely related”

2. These groups are recognized by sharing unique features which were not present in distant ancestors.

3. These **derived characteristics** are called **apomorphies**.

4. If shared among species they indicate the species are closely and are referred to as **shared derived characteristics** called **synapomorphies**.
Two descendant populations with shared derived characteristics

Two descendant populations, each with unique derived traits

Ancestral population

Synapomorphy traits

Apomorphy traits

Plesiomorphy traits
The convention is to call the "original" state of the characteristic **plesiomorphic** ("primitive" or ancestral) and the "changed" state **apomorphomic** ("derived")
Cladistic clusters closely related organisms based on shared derive characteristic (shared apomorphomic traits, not just apomorphic traits) called synapomorphic traits.
(a) Two descendant populations, each with unique derived traits

(b) Four descendant populations, each with unique derived traits

Ancestral population
The most widely accepted method in systematics is **cladistics**

- Cladistics makes use of and differentiates between
  - Plesiomorphic traits – not informative
  - Apomorphic traits – not informative
  - Synapomorphous traits – informative

- Cladistics clusters organisms into closely related groups or lineages that share derived traits called synapomorphous traits
Evolutionary history of birds

1. Origin of birds is traced back to the **mesozoic era** 208-144 mya (**Jurassic period**)

Rapid radiation of birds is determined to have occurred in the **Cenozoic Era** 65-57mya (**paleocene period**)
Geological time scale
Archeopteryx.

- An early fossil bird from the Jurassic, ca 150 mya: Archaeopteryx, Greek for "ancient wing," the link between birds and reptiles, looked like a small dinosaur with feathers.
- Fossils were found in Germany.
Archaeopteryx is an odd mix of reptilian (ancestral, or plesiomorphic - shared with ancestral groups) and bird-like (derived) traits.

Apomorphic states (derived bird like)
1. Has a furculum (fused wishbone)
2. Had feathers
3. fused sclerotic ring
4. Three wing digits with phalangeal formula 2,3,4
5. partly fused tarsometatarsus
6. Four Toe digits with 2-3-4-5 phalangeal formula.
Plesiomorphic (primitive traits)

1. Teeth in jaw, curved backward
2. Snout rather than a bill
3. Small braincase
4. Large olfactory lobes
5. Abdominal ribs or gastralia.
6. Unfused caudal vertebrae, n=23
7. Sternum showed no keel
8. No foramen triosseum between the coracoid, sternum and clavicles
9. It had unfused carpals and metacarpals.
10. Long grasping forelimbs; horny and bony claws on end of digits
11. A long balancing tail