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**Evolution**

**Definition**
- Evolution is the permanent genetic change in a population of individuals.
- It does not refer to changes that occur to an individual within its own lifetime – individuals do not evolve, but populations can.

**Microevolution**
- Small-scale changes within gene pools over generations is called **microevolution**.

**Macroevolution**
- Evolutionary change on a large scale, involving whole groups of species and genera, is called **macroevolution**.
- Macroevolution includes:
  1. Adaptive radiation of groups of species into different environments.
  2. The origin of evolutionary novelties such as the wings and feathers of birds, and the upright posture of humans.
- The evolutionary history of a species or taxonomic group is called its **phylogeny**.
Evidence for Evolution

- Evolutionary theory is now supported by a wealth of observations and experiments.
- Although biologists do not always agree on the exact mechanisms of population change, the fact that evolution has taken place is well documented.
- Evidence for evolution comes from a variety of sources:
  1. **Palaeontology**: The identification, interpretation and dating of fossils. This gives us some of the most direct evidence of evolution.
  2. **Embryology**: The study of the embryonic development of different organisms.
  3. **Comparative Anatomy**: The study of the structure of particular organs in different organisms.
  4. **Biogeography**: The study of geographic distributions can indicate where species may have originally arisen.
  5. **Artificial Breeding**: Selective breeding of plants and animals has shown that certain phenotypic characteristics can be ‘selected for’ in offspring.
  6. **Biochemistry**: Similarities and differences in the biochemical make-up of organisms can closely parallel similarities and differences in appearance.
  7. **Molecular Biology**: Sequencing of DNA and proteins indicates the degree of relatedness between organisms.
Interpretation of Fossils

- The term **fossil** refers to any parts or impressions of a plant or animal that may survive after its death.

- Fossils form best when organisms are buried quickly in conditions that slow the process of decay.

- Fossils are most commonly found in sedimentary rock.

- The age of a fossil may be determined by using one of the following **absolute dating methods**:

<table>
<thead>
<tr>
<th>Dating Method</th>
<th>Age Range (years ago)</th>
<th>Material Dated</th>
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<tr>
<td>Potassium/Argon</td>
<td>10,000 – 100 million</td>
<td>Volcanic rocks</td>
</tr>
<tr>
<td>Carbon 14</td>
<td>1,000 – 50,000+</td>
<td>Bone, shell, charcoal</td>
</tr>
<tr>
<td>Uranium/Thorium</td>
<td>Less than 350,000</td>
<td>Bone, tooth dentine</td>
</tr>
<tr>
<td>Thermoluminescence</td>
<td>less than 200,000</td>
<td>Pottery, fired clay, bricks, burned rock</td>
</tr>
<tr>
<td>Amino acid racemization</td>
<td>1 million – 2,000</td>
<td>Bone</td>
</tr>
<tr>
<td>Obsidian Hydration</td>
<td>800,000 – present</td>
<td>Obsidian (volcanic glass)</td>
</tr>
<tr>
<td>Fission Track</td>
<td>1 million – 100,000</td>
<td>Volcanic rock</td>
</tr>
<tr>
<td>Electron Spin Resonance</td>
<td>500,000 – 1,000</td>
<td>Bone, tooth enamel, cave deposits</td>
</tr>
</tbody>
</table>

A fossil trilobite, a primitive arthropod that dwelled in the seas of the Devonian period 370 million years ago.
Fossils in a Rock Profile

- Layers of sedimentary rock are arranged in the order in which they were deposited, with the most recent layers nearer the surface (unless they have been disturbed).

- Interpretation of rock layers containing fossils allows us to arrange the fossils in chronological order (order of occurrence), but does not give their absolute date.

Recent fossils are found in recent sediments

Numerous extinct species

Fossil types differ in each sedimentary rock layer

New fossil types mark changes in environment

Only primitive fossils are found in older sediments

Set 7: Evolution
The Fossil Record

Although incomplete, the fossil record can tell us much about the history of life on Earth:

1. Fossil species are often similar to, but usually differ from, today's species.
2. Fossil types often differ between sedimentary rock layers.
3. Fossils can be dated to establish their approximate absolute age.
4. Older sediments have older fossils while more recent sediments have more recent fossils.
5. Numerous extinct species are found as fossils.
6. New fossil types mark changes in the past environmental conditions on the Earth.
7. Modern day species can be traced through fossil relatives to distant origins.
8. Rates of evolution can vary, with bursts of species formation followed by stable periods.

Set 7: Evolution

Mammoth
Pleistocene

Archaeopteryx
Jurassic
The history of life is divided up into eons, epochs, eras and periods:

- **Archean Eon**
  - Oldest known microfossils found in 3,500 million year old chert in Western Australia

- **Proterozoic Eon**
  - Oxygen produced by plants accumulates in the atmosphere

- **Cambrian**
- **Ordovician**
- **Silurian**
- **Devonian**
- **Carboniferous**
- **Permian**
- **Triassic**
- **Jurassic**
- **Cretaceous**
- **Tertiary**

- **Quaternary**

**The History of Life on Earth**

- Formation of the earth: 4,600 mya
- Oldest known microfossils found in 3,500 million year old chert in Western Australia
- Oxygen produced by plants accumulates in the atmosphere

**Time Scale**

- **Precambrian**
- **Proterozoic**
- **Palaeozoic**
- **Mesozoic**
- **Cenozoic**

**Millions of years ago**

- 4,500
- 4,000
- 3,500
- 3,000
- 2,500
- 2,000
- 1,500
- 1,000
- 500
- 0
Based on fossil evidence and radio-isotope dating, the evolutionary history of non-chordates can be compiled:

- **Bacteria and algae**
- **Protists**
- **Fungi**

- **Sphenophytes** (ferns etc.)
- **Conifers**
- **Cycads**
- **Angiosperms**

- **Cnidarians** (Coelenterates)
- **Flatworms**
- **Molluscs**
- **Annelid worms**
- **Insects**
- **Crustacea**
- **Diplopoda** (centipedes etc.)
- **Arachnids** (spiders etc.)
- **Echinoderms**

**Millions of years ago**

- **600**
- **500**
- **400**
- **300**
- **200**
- **100**
- **0**

**Periods:**

- **Precambrian**
- **Cambrian**
- **Ordovician**
- **Silurian**
- **Devonian**
- **Carboniferous**
- **Permian**
- **Triassic**
- **Jurassic**
- **Cretaceous**
- **Tertiary**
- **Quaternary**
Evolutionary History 2

Based on fossil evidence and radio-isotope dating, the evolutionary history of chordates can be compiled:

- **Tunicates**
- **Agnatha** (jawless fish)
- **Sharks and Rays**
- **Ray-finned fish**
- **Lungfish**

- **Amphibians**
- **Turtles**
- **Crocodiles & alligators**
- **Rhyncocephalia** (tuatara)
- **Squamata** (lizards & snakes)

- **Birds**
- **Monotremes**
- **Marsupials**
- **Placentals**

Millions of years ago:

- **Precambrian**
- **Cambrian**
- **Ordovician**
- **Silurian**
- **Devonian**
- **Carboniferous**
- **Permian**
- **Triassic**
- **Jurassic**
- **Cretaceous**
- **Tertiary**
- **Quaternary**
Precambrian Life

- **4,600 mya**: Origin of Earth.
- **4,600–3,800 mya**: Chemical and molecular evolution leading to origin of life: protocells to anaerobic bacteria.
- **3,800–2,500 mya**: Origin of photosynthetic bacteria.
- **2,500–570 mya**: Origin of protists, fungi, algae, and animals.

Set 7: Evolution
Early Palaeozoic Life

- **550-500 mya**: Origin of animals with hard parts, which appear as fossils in sedimentary rocks.
- Simple marine communities become established.
- A famous Canadian site with a rich collection of early Cambrian fossils is known as the Burgess Shale deposits. Examples are shown below:

![Anomalocaris](image)

![Aysheaia](image)

![Hallucigenia](image)

![Ottoia](image)

![Wiwaxia](image)

![Pikaia](image)

550-500 mya: Origin of animals with hard parts, which appear as fossils in sedimentary rocks.

Simple marine communities become established.

A famous Canadian site with a rich collection of early Cambrian fossils is known as the Burgess Shale deposits. Examples are shown below:
Late Palaeozoic Life

- **500-435 mya**: Major adaptive radiations of marine invertebrates and early fishes.
- **435-280 mya**: Vast swamps with the first vascular plants. Origin and adaptive radiation of reptiles, insects, and spore bearing plants (including gymnosperms).
- **240 mya**: Mass extinction of nearly all species on land and in the sea.

---

- Early insects
- Dimetrodon
- Early vascular plants
- Armoured fish
- Ammonite
- Trilobite
- Early amphibians

---

Set 7: Evolution
**Mesozoic Life**

- **181-135 mya**: Major radiations of dinosaurs.
- **65 mya**: Apparent asteroid impact causes mass extinctions of many marine species and all dinosaurs.

**Set 7: Evolution**
Cenozoic Life

- **65-1.65 mya**: Major shifts in climate. Major adaptive radiations of angiosperms (flowering plants), insects, birds and mammals.
- **3-5 mya**: Early humans arise from ape ancestors.
- **1.65 mya**: Modern humans evolve and their hunting and other activities accelerate.

Set 7: Evolution
Comparative Embryology

- Although the early developmental sequences between all vertebrates are similar, there are important deviations from the general developmental plan in different species.
- Similarity in development could be expected if all vertebrates were descended from a common ancestor.

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<th>Developmental Stage</th>
<th>Amphibian</th>
<th>Bird</th>
<th>Monkey</th>
<th>Human</th>
</tr>
</thead>
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<tr>
<td>Fertilised Egg</td>
<td><img src="image1" alt="Amphibian" /></td>
<td><img src="image2" alt="Bird" /></td>
<td><img src="image3" alt="Monkey" /></td>
<td><img src="image4" alt="Human" /></td>
</tr>
<tr>
<td>Late Cleavage</td>
<td><img src="image5" alt="Amphibian" /></td>
<td><img src="image6" alt="Bird" /></td>
<td><img src="image7" alt="Monkey" /></td>
<td><img src="image8" alt="Human" /></td>
</tr>
<tr>
<td>Body Segments</td>
<td><img src="image9" alt="Amphibian" /></td>
<td><img src="image10" alt="Bird" /></td>
<td><img src="image11" alt="Monkey" /></td>
<td><img src="image12" alt="Human" /></td>
</tr>
<tr>
<td>Limb Buds</td>
<td><img src="image13" alt="Amphibian" /></td>
<td><img src="image14" alt="Bird" /></td>
<td><img src="image15" alt="Monkey" /></td>
<td><img src="image16" alt="Human" /></td>
</tr>
<tr>
<td>Late Foetal</td>
<td><img src="image17" alt="Amphibian" /></td>
<td><img src="image18" alt="Bird" /></td>
<td><img src="image19" alt="Monkey" /></td>
<td><img src="image20" alt="Human" /></td>
</tr>
</tbody>
</table>

Although the early developmental sequences between all vertebrates are similar, there are important deviations from the general developmental plan in different species. Similarity in development could be expected if all vertebrates were descended from a common ancestor.
Anatomical Similarity

- The pentadactyl (5 digit) limb found on most vertebrates has the same general bone structure. This similarity is called **homology**.
- Forelimbs and hind limbs have different names for equivalent bones.

**Forelimb**
- **Humerus** (upper arm)
- **Ulna**
- **Radius**
- **Carpals** (wrist)
- **Metacarpals** (palm)
- **Phalanges** (fingers)

**Hind Limb**
- **Femur** (thigh)
- **Fibula**
- **Tibia**
- **Tarsals** (ankle)
- **Metatarsals** (sole)
- **Phalanges** (toes)
Homologous Structures

Many mammals have limb bones that have been highly modified to give a specialised locomotory function.

- Bird's wing
- Mole's forelimb
- Dog's front leg
- Bat's wing
- Seal's flipper
- Human arm

Set 7: Evolution
Analogous Structures

- Not all similarity is inherited from a common ancestor.
- Organs that have the same function in different organisms may come from quite different origins.
- Analogous structures do not imply an evolutionary relationship, but may illustrate convergence.

Examples: Eye structure of the octopus and mammals. Wing structure of a bird and a moth.
Vestigial Organs

- Many organisms have degenerate organs or structures that no longer perform the same function as in other organisms.
- Presumably these organs were important in some ancestral form, but became redundant in later species.
- The selection pressure for their complete loss is weak so these structures remain in a reduced form.
- Apparently, these vestigial organs have little use, although they often perform some secondary function.

Examples:

1. In humans, the **appendix** is often regarded as a vestigial organ because it no longer has a digestive function as it does in many other mammals.
   However, it may still have an immune function in its degenerate state.

2. The **tiny pelvis** and **femur** of **whales** are no longer used for the attachment of hind limbs.

3. The **vestigial eyes** of **burrowing animals** are no longer used for vision.

4. The **wisdom teeth** of humans have little value in chewing.
Vestigial Organs in Whales

- Whales are the descendants of large, four-legged land mammals that took up an aquatic existence some 60 million years ago.

- Over many millions of years, the pelvis and femur of whales have become very small and no longer fulfill a locomotory function.
Biogeographical Evidence

- The study of plant and animal distribution is called biogeography.

- The basic principle of biogeography is that each plant and animal species originated only once. The place where this occurred is the centre of origin.

- The range of a species can be very restricted or, as with humans, almost the whole world (cosmopolitan).

- Regions that have been separated from the rest of the world for a long time, e.g. Australia and New Zealand, often have distinctive biota comprising of a large number of endemic species (species that are found nowhere else).

- General principles about the dispersal and distribution of land animals are:
  1. Closely related animals in different geographic areas probably had no barrier to dispersal in the past.
  2. The most effective barrier to dispersal in land animals was sea (as when sea levels changed).
  3. The discontinuous distribution of modern species may be explained by movement out of the area they originally occupied, or by extinction.

- Oceanic islands often have species that are similar to, but distinct from, those on neighbouring continents.
  The occurrence of these species suggests that they were island colonisers that evolved in isolation differently to their ancestors on the mainland.
The Biogeography of the Camel Family

- The camel family comprises of 6 modern-day species that have survived on three continents.
- There are no surviving species on their continent of origin, North America, where they emerged about 40 million years ago and later dispersed to other continents.

**Camel ancestor in North America 40 million years ago**

**Four llama species:** llama, alpaca, guanaco and vicuña

**Land bridge across the Bering Strait 1 million years ago**

**Recent Distribution**

**Tertiary Distribution**

- Arabian camel *Camelus dromedarius*
- Bactrian camel *Camelus bactrianus*
- Llama *Lama glama*
- Vicuña *Vicugna vicugna*
- Guanaco *Lama guanicoe*
The distribution of species around the world suggests that modern forms evolved from ancestral populations and spread out (radiated) out into new environments.

Good examples are found on islands offshore from large continental land masses.

**Galapagos Islands**
The Galapagos Islands have species very similar to, but distinct from, the South American mainland. Ancestral forms probably migrated to the islands from the mainland in the past.

**Cape Verde Islands**
Species on the Cape Verde Islands have close relatives on the West Africa mainland. There are relatively few animals and no indigenous mammals.

---

Set 7: Evolution
The Biogeography of Tristan da Cunha

The island of Tristan da Cunha, in the South Atlantic Ocean, provides good evidence of the evolution of new species from ancestral ones.

Plant species on the island are of either South American origin, African origin or both (universal origin).

Despite the fact that Africa is considerably closer, more species show South American affinities than African ones.

This is probably due to the predominant westerly trade winds from the direction of South America.

South American Origin
- 7 Flowering Plants
- 5 Ferns
- 30 Liverworts

African Origin
- 2 Flowering Plants
- 2 Ferns
- 5 Liverworts

Universal Origin
- 19 Flowering Plants
Island Colonisers 1

- Species may reach offshore islands (that provide new habitats) in a number of ways:

  *Flight, rafting across water, being passively blown by the prevailing winds, etc.*

- Very mobile species such as seabirds with the ability for strong, prolonged flight, are not easily isolated in one area and are often widespread (cosmopolitan) in their distribution.

- Very mobile terrestrial species may be isolated by changes in the environment caused by major geological events (e.g. volcanic activity, sea level rise).

- Many species that become permanently isolated on offshore islands have low mobility and weak powers of dispersal.

  They may be blown to an island by the prevailing wind and be unable to return (e.g. bats, small birds, insects).

- Other animals may be good colonisers because they can survive periods of food and water deprivation while making the journey to the island by sea (e.g. reptiles).

- Successful colonisers of islands are often adaptable in their food and habitat requirements.

- In the new environment, species may later become more specialised as they exploit a new range of resources.
Island Colonisers 2

**Land Mammals** rarely colonise islands. A high metabolic rate requires much food and water. Mammals cannot sustain themselves on long sea journeys.

**Reptiles** probably reach distant islands by floating in driftwood. A low metabolic rate enables them to survive long periods without food and water.

**Amphibians** cannot live away from fresh water. They seldom reach offshore islands unless that island is a continental remnant.

**Small Birds, Bats, and Insects** are blown to islands by accident. They must adapt to life there or perish.

**Seabirds** fly to and from islands with relative ease. Some adapt to life on land, (e.g. the flightless cormorant in the Galapagos Islands). Others, may treat the island as a stopping place (e.g. the frigate bird).

**Sea Mammals** have little difficulty in reaching islands (e.g. seals, sea lions). They do not colonise the interior of islands.

**Crustacean larvae** drift to islands (e.g. crabs). Some crabs have adapted to an island niche.

**Oceanic island**

- **Blown by strong winds**
- **Active flight**
- **Rafting on drifting vegetation**
- **Swimming**
- **Deep ocean**
- **Planktonic larvae**
One way to reconstruct the evolutionary history of a species is using DNA hybridisation.

In this technique the DNA from different species is ‘unzipped’ and recombined to form hybrid DNA.

Heat can be used to separate the hybridised strands. The amount of heat required to do this is a measure of how similar the two DNA strands are (% bonding).

EXAMPLE:

The relationships among the New World vultures and storks has been determined on the basis of DNA hybridisation.
DNA Hybridisation Method

DNA is isolated from blood samples from each species:

Extract Human DNA

Unzip the DNA using heat (both human and chimpanzee DNA unwinds at 86°C)

Mix strands to form a hybrid

Some of the opposing bases in the DNA sequence do not match

Extract Chimpanzee DNA

The greater the similarity in DNA base sequence, the stronger the attraction between the two strands and therefore they are harder to separate again.

By measuring how hard this hybrid DNA is to separate, a crude measure of DNA relatedness can be achieved.

The degree of similarity of the hybrid DNA can be measured by finding the temperature that it unzips into single strands again (in this case it would be 83.6°C).
Recent advanced techniques have enabled the sequence of DNA in different species to be determined.

Species thought to be closely related on the basis of other evidence, were found to have a greater percentage of DNA sequences in common.

Humans and chimpanzees have a 97.6% similarity in their DNA sequences and are very closely related.

An interesting finding was that the DNA of humans and chimpanzees is more closely matched than that of chimpanzees and gorillas.

**DNA Sequencing**

<table>
<thead>
<tr>
<th>Species</th>
<th>DNA Similarity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Human</td>
<td>100%</td>
</tr>
<tr>
<td>Chimpanzee</td>
<td>97.6%</td>
</tr>
<tr>
<td>Gibbon</td>
<td>94.7%</td>
</tr>
<tr>
<td>Rhesus Monkey</td>
<td>91.1%</td>
</tr>
<tr>
<td>Vervet Monkey</td>
<td>90.5%</td>
</tr>
<tr>
<td>Capuchin Monkey</td>
<td>84.2%</td>
</tr>
<tr>
<td>Galago</td>
<td>58.0%</td>
</tr>
</tbody>
</table>
Amino Acid Sequencing 1

- The sequences of amino acids in certain proteins (e.g. **haemoglobin** and **cytochrome C**) have revealed great similarities and specific differences between species.
- Closely related species have proteins with similar amino acid sequences.
- Amino acid sequences are determined by inherited genes and differences are due to mutations.
- The degree of similarity of these proteins is determined by the number of mutations that have occurred. Distantly related species have had more time for differences to accumulate:
  1. The greater the elapsed time since common ancestry, the greater the time for mutations to occur.
  2. This in turn leads to a greater difference in amino acid sequences between species.
Amino Acid Sequencing 2

Amino acid differences for β-haemoglobin in primates compared to the human sequence:

<table>
<thead>
<tr>
<th>Primate</th>
<th>No. of Amino Acids Different from Humans</th>
<th>Position of Changed Amino Acids</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chimpanzee</td>
<td>Identical</td>
<td>–</td>
</tr>
<tr>
<td>Gorilla</td>
<td>1</td>
<td>104</td>
</tr>
<tr>
<td>Gibbon</td>
<td>3</td>
<td>80 87 125</td>
</tr>
<tr>
<td>Rhesus monkey</td>
<td>8</td>
<td>9 13 33 50 76 87 104 125</td>
</tr>
<tr>
<td>Squirrel monkey</td>
<td>9</td>
<td>5 6 9 21 22 56 76 87 125</td>
</tr>
</tbody>
</table>

The ‘position of changed amino acids’ is the point in the protein, composed of 146 amino acids, at which a different amino acid occurs.
Immunological Techniques

Immunology indirectly measures the degree of similarity of proteins in different species.

EXAMPLE: Anti-human antibodies are developed in a rabbit and added to the blood of other species. The greater the similarity between humans and the blood of other species the greater the antibody-antigen reaction.

1 Human serum is injected into a rabbit
2 Rabbit serum with anti-human antibodies extracted
3 Rabbit serum added to blood of other species

Precipitate forms

Human, Gorilla, Baboon, Lemur, Rat

Decreasing recognition of anti-human antibodies to blood proteins
Immunological Evidence

The evolutionary relationships of a large number of different animal groups have been established on the basis of immunology.

The results support the phylogenies developed from other areas of biology: biogeography, comparative anatomy, morphological studies, and fossil evidence.

**Example**: relatedness of tree frogs.

The phylogeny (evolutionary relationships) of tree frogs has been established by immunology.

The immunological distance is the number of amino acid substitutions between taxa.

![Immunological Evidence Diagram](image)

- Australian treefrogs diverge from other tree frogs more than 35 million years ago.
Contributors to the development of Darwin’s ideas were:

- **Jean Baptiste de Lamarck** (1744-1829)
  Believed that organisms could pass on traits acquired during their lifetime.
  - **Discredited**: when the mechanisms of heredity became known.
  - **Important**: because he was the first to propose that change over time was the result of natural phenomena and not divine intervention.

- **Thomas Malthus** (1766-1834)
  Believed that populations increased in size until checked by the environment, called the ‘struggle for existence’.

- **Charles Lyell** (1797-1875)
  Developed the geological theory of uniformitarianism: the physical features of the earth were the result of slow geological processes that still occur today.

- **Hebert Spenser** (1820-1903)
  Introduced the concept of ‘Survival of the Fittest’.
The Modern Theory of Evolution

The **modern theory of evolution** combines the following ideas:

– Darwin’s theory of the origin of species by **natural selection**.

– with an understanding of **genetics** (from Mendel).

– and the **chromosomal basis of heredity** (from Weismann).

This synthesis is called **NEO–DARWINISM**
The Development of Darwin’s Ideas

- The first convincing case for evolution, *The Origin of Species*, was published by Charles Darwin in 1859.
- In *The Origin of Species*, Darwin argued that new species developed from ancestral ones by natural selection.
- Darwin developed his theory of “survival of the fittest” by building on earlier ideas and supporting his views with a large body of evidence he collected while voyaging extensively on the ship the ‘HMS Beagle’.
- Alfred Russel Wallace, a young specimen collector working in the East Indies, developed a theory of natural selection independently of Darwin. However, Darwin supported the theory more extensively and receives most of the credit for it.

- Darwin’s theory was supported by data collected from:
  1. The flora and fauna of South America. These showed different adaptations for diverse environments but were distinct from the European forms.
  2. Observations of the fauna of the Galapagos Islands confirming his already formulated ideas from earlier in the trip. He found that most of the Galapagos species are endemic, but resembled species on the South American mainland.
  3. Fossil finds of extinct species.
  4. Evidence from artificial (selective) breeding.
History of Evolutionary Thought

Erasmus Darwin
1731 - 1802
Charles Darwin's grandfather and probably an important influence in developing his thoughts on evolution.

John Baptiste de Lamarck
1744 - 1829
First to publish a reasoned theory of evolution. Proposed idea of use and disuse and inheritance of acquired characteristics.

Rev. Thomas Malthus
1766 - 1834

Hebert Spencer
1820 - 1903
Proposed concept of the 'survival of the fittest'

Charles Lyell
1797 - 1875
Major influence on Darwin. Lyell's work 'Principles of Geology' proposed that the earth is very old.

Alfred Russel Wallace
1823 - 1913
'Theory of Natural Selection'

Gregor Mendel
1822 - 1884
Developed the fundamentals of the genetic basis of inheritance.

August Weismann
1834 - 1914
Proposed chromosomes as the basis of heredity, demolishing the theory that acquired characteristics could be inherited.

R.A. Fisher
1890-1962
J.B.S. Haldane
1898-1964
Sewall Wright
1889-1988
Founding of population genetics and mathematical aspects of evolution and genetics.

The New Synthesis
Neo-Darwinism: The version of Darwin's theory refined and developed in the light of modern biological knowledge (especially genetics) in the mid-20th century

Charles Darwin
1809 - 1882
'Theory of Evolution by Natural Selection'

Julian Huxley
1887-1975
Ernst Mayr
1904 -
T. Dobzhansky
1900-1975
Collaborated to formulate the modern theory of evolution, incorporating developments in genetics, palaeontology and other branches of biology.

Set 7: Evolution
The Concepts of Darwinism

Darwin’s view of life was of ‘descent with modification’: descendants of *ancestral forms* adapted to different environments over a long period of time.

The mechanism for adaptation is called ‘natural selection’, and is based on a number of principles:

1. **Overproduction**
   Species produce more young than will survive to reproductive age (they die before they have offspring).

2. **Variation**
   Individuals vary from one another in many characteristics (even siblings differ). Some variations are better suited then others to the conditions of the time.

3. **Competition**
   There is competition among the offspring for resources (food, habitat etc.).

4. **Survival of the Fittest Phenotype**
   The individuals with the most favourable combinations of characteristics will be most likely to survive and pass their genes on to the next generation.

5. **Favourable Combinations Increase**
   Each new generation will contain more offspring from individuals with favourable characters than those with unfavourable ones.
Darwin’s Theory of Natural Selection

**Overproduction**
Populations produce too many young: many must die

**Variation**
Individuals show variation: some are more favourable than others

**Natural Selection**
Natural selection favours the best suited at the time

**Inheritance**
Variations are Inherited. The best suited variants leave more offspring.

---

Set 7: Evolution
Species

- A **biological species** is a group of interbreeding (or potentially interbreeding) individuals, reproductively isolated from other such groups.

- Species are often composed of different populations (often in different habitats) that are quite distinct.

These are often called **subspecies**, **races**, and **varieties** depending on the degree of reproductive isolation.

- The boundaries of a species gene pool can be sometimes unclear, such as the genus to which all dogs, wolves, and related species belong:

  - **Coyote**: *Canis latrans*
  - **Red Wolf**: *Canis rufus*
  - **Domestic Dog**: *Canis familiaris*
  - **Grey Wolf**: *Canis lupus*
  - **Golden Jackal**: *Canis aureus*
  - **Black-backed Jackal**: *Canis mesomelas*
  - **Side-striped Jackal**: *Canis adjustus*
  - **Dingo**: *Canis familiaris dingo*

**Set 7: Evolution**
Definition of a biological species does not apply in all situations:
1. The concept of a species being able to interbreed cannot apply to extinct populations because this is unknown: extinct forms must usually be classified on morphological grounds.
2. Asexually reproducing organisms do not breed with each other and so are assigned to species on the basis of appearance or biochemical similarities.

Even for sexually reproducing organisms, a species may grade (show a gradual change) in phenotype over a geographic area. Such a continuous gradual change is called a cline and often occurs along the length of a country or continent.

All the populations are of the same species as long as interbreeding populations link them.

A particular kind of clinal variation occurs with ring species.

Set 7: Evolution
Ring Species 1

A **ring species** is a special type of **cline** that forms a loop, resulting in the two ends of the cline overlapping with each other.

In such cases, the species occupies a very wide geographic area, where individuals at the ends of the cline can be very different from one another.

A classic example of a ring species is the **herring gull** and the **lesser black-backed gull**.

- Their distribution forms a complete circle around the North Pole.

- The two gull forms overlap in Britain and Western Europe, but rarely interbreed and behave as two distinct species.

- However, they are connected by a series of intermediate, interbreeding populations.
Below is the geographical distribution of the herring gull and the lesser black-backed gull.

Herring gulls fly eastwards across the North Atlantic Ocean to Europe

| Zone of intermediate species capable of interbreeding with neighbouring populations. | 1 → 4 | Gulls are recognisable as herring gulls and are classified as various subspecies of *L. argentatus*. |
| Zone of overlap between the gulls at the extreme ends of the cline. | 5 → 7 | Gulls are recognisable as lesser black-backed gulls and are classified as various subspecies of *L. fuscus*. |
Reproductive Isolating Mechanisms

Reproductive Isolating Mechanisms (RIMs) prevent successful breeding between different species. They are barriers to gene flow.

A single barrier may not completely isolate a gene pool, but most species have more than one isolating mechanism operating to maintain a distinct gene pool.

Geographical barriers prevent species interbreeding but are not considered to be RIMs because they are not operating through the organisms themselves.

Reproductive isolating mechanisms can be categorised according to when and how they operate:

1. **Prezygotic** (pre-fertilisation) mechanisms include:
   - habitat preference
   - behavioural incompatibility
   - structural incompatibility
   - physiological incompatibility

2. **Postzygotic** (post-fertilisation) mechanisms include:
   - zygote mortality
   - poor hybrid fitness
   - hybrid sterility
Prezygotic Isolating Mechanisms 1

Prezygotic isolating mechanisms act **before** fertilisation to prevent successful reproduction.

**Ecological or Habitat**
Different species may occupy different habitats within the same region e.g. aquatic and terrestrial species.

**Desert Habitat**

**Coastal Habitat**

These closely related snakes of the same genus do not interbreed because they do not get the opportunity to meet.

Set 7: Evolution
Prezygotic Isolating Mechanisms 2

Temporal (Time)
Species may have different activity patterns – they may be nocturnal or diurnal, or breed at different seasons.

In the hypothetical example below, the two species of butterfly will never mate because they are sexually active at different times of the year:

Breeding season for Species A

Breeding season for Species B
Prezygotic Isolating Mechanisms 3

Behavioural
Species may have specific calls, rituals, postures etc. that enable them to recognise potential mates (many bird species have elaborate behaviours).

Structural
For successful mating, species must have compatible copulatory apparatuses, appearance, and chemical make-up (odour, chemical attractants).

Gamete Mortality
If sperm and egg fail to unite, fertilisation will be unsuccessful.

Insects have very specific copulatory organs that act like a lock and key.
Postzygotic Isolating Mechanisms

- Postzygotic isolating mechanisms act after fertilisation to prevent successful reproduction.

**Hybrid Inviability**
The fertilised egg may fail to develop properly. Fewer young may be produced and they may have a low viability (survivability).

**Hybrid Sterility**
The hybrid of two species may be viable but sterile, unable to breed (e.g. the mule).

**Hybrid Breakdown**
The first generation may be fertile but subsequent generations are infertile or non-viable.

This mule is a hybrid between a horse and a donkey.

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**Set 7: Evolution**

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OHT 47
Hybrids in the Horse Family

- Sterile hybrids are common among the horse family.
- The chromosomes of the zebra and donkey parents differ in number and structure, producing a sterile “zebronkey”.

**Zebra stallion** (2n = 44)  **Donkey mare** (2n = 62)

Karyotype of ‘Zebronkey’ offspring (2n = 53)

Chromosomes contributed by zebra father

Chromosomes contributed by donkey mother

Set 7: Evolution
**Speciation**

- **Speciation** refers to the process by which new species are formed.

- Speciation occurs when gene flow has ceased between populations where it previously existed.

- Speciation is brought about by the development of reproductive isolating mechanisms which maintain the integrity of the new gene pool.

- Taking a very simple view, speciation can happen in one of two ways:
  - **Splitting**: A species could split fairly equally into two populations that evolve differently until they eventually become separate species.
  - **Budding**: A small part of the species population could “bud off” from the main part and evolve rapidly (in geological time-scale terms) to form a new species while leaving most of the original species population unchanged.

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**Set 7: Evolution**
Types of Speciation

There are several models proposed to account for the formation of new species among sexually reproducing organisms:

1. **Allopatric speciation**: Populations become geographically separated, each being subjected to different natural selection pressures, and finally establishing reproductive isolating mechanisms.

2. **Sympatric speciation**: Occurs when a population forms a new species within the **same area** as the parent species.
   - There is no geographical separation between the speciating populations.
   - All individuals are, in theory, able to meet each other during the speciation process.

   Several models have been proposed for this type of speciation, involving one of the following:
   - A change in host preference, food preference or habitat preference.
   - The partitioning of an essential but limiting resource.
   - Instant speciation as a result of **polyploidy** (particularly among plants as in the evolution of wheat).

3. **Parapatric speciation**: The speciating populations are only partially separated geographically, so some individuals on each side are able to meet across a common boundary during the speciation process.

   Sympatric speciation is thought to be rarer than allopatric speciation among animals, although it is probably a major cause of speciation among plants.
Allopatric Speciation 1

STAGE 1: Moving Into New Environments

- The parent population expands its range and occupies new parts of the environment.
- Expansion of the range may be due to competition.
- The population has a common gene pool with regular gene flow (any individual has potential access to all members of the opposite sex for the purpose of mating).

Set 7: Evolution
Allopatric Speciation 2

STAGE 2: Geographical Isolation

- Gradual formation of physical barriers may isolate parts of the population at the extremes of the species range.
- As a consequence, gene flow between these isolated populations is prevented or becomes rare.
- Agents causing geographical isolation include: continental drift, climatic change, and changes in sea level (due to ice ages).

Set 7: Evolution
Allopatric Speciation 3

STAGE 3: Formation of a Subspecies

- The isolated populations may be subjected to quite different selection pressures.
- These selection pressures will favour those individuals with traits suited to each environment.
- Allele frequencies for certain genes change and the populations take on the status of a subspecies (reproductive isolation is not yet established).

Set 7: Evolution
STAGE 4: Reproductive Isolation

- Each separated subspecies undergoes changes in its genetic makeup and behaviour. This will prevent mating with individuals from the other populations.
- Each subspecies’ gene pool becomes reproductively isolated from the others and they attain species status.
- Even if geographical barriers are removed to allow mixing of the populations, genetic isolation is complete.

**Sympatric species:** Closely related species with overlapping distribution

**Allopatric species:** Closely related species still geographically separated
Sympatric Speciation 1

Habitat Preference

- It is not uncommon for some insect species to be conditioned to lay eggs on the plant species on which they themselves were reared.
  - If the normally preferred plant species is unavailable, then the insect may be forced to choose another species to lay eggs on.
  - A few eggs surviving on this new plant will give rise to a new population with a new plant species preference.

An insect forced to lays its eggs on an unfamiliar plant species may give rise to a new population of flies isolated from the original population.

Original Host Plant Species

New Host Plant Species
Sympatric Speciation 2

Establishing Reproductive Isolation

- If mating and rearing of offspring takes place entirely within the habitat, then the population will become reproductively isolated.
- Further differentiation of the two populations is likely as each becomes increasingly adapted to their respective habitats.
- Ultimately, the two groups will diverge to be recognised as separate species.

Gene flow

Original host plant species

No gene flow

New host plant species

Each host plant will attract flies that were reared on that plant where they will mate with other flies with a similar preference
Sympatric Speciation 3

- **Polyploidy** involves the multiplication of whole sets of chromosomes (each set being the haploid number n).
- Polyploids occur frequently in plants and in some animal groups such as rotifers and earthworms.
- When such individuals spontaneously arise, they are **instantly** reproductively isolated from their parent population.
- As many as 80% of flowering plant species may have originated as polyploids. Different species of *Chrysanthemum* (some examples are shown below) have arisen as a result of polyploidy. They have chromosome numbers (2n) that are multiples of 18: \(2n = 18, 36, 54, 72, \) and 90.
Different types of isolating mechanisms operate and different amounts of gene flow take place as two populations diverge to form new species:

- **Population A**
  - Race A
    - Subspecies A
      - Species A

- **Population B**
  - Race B
    - Subspecies B
      - Species B

### Isolating Mechanisms
- **Geographic isolation**
- **Prezygotic isolation**
- **Postzygotic isolation**

### Gene Flow
- **Gene flow common**
- **Gene flow uncommon**
- **Gene flow very rare**
- **No gene flow**

---

**Set 7: Evolution**
Life Cycle of Species

- Species undergo a ‘life cycle’ of developmental stages including formation, maturation and final extinction.
- It has been estimated from the fossil record that this cycle may take, on average, from between 1 to 20 million years, depending on the species.

**Origin**
- Favourable mutations or new combinations can lead to formation of new species

**Extinction**
- Reduction in range and numbers

1. **Neospecies**
   - Increasing range and numbers
   - Increasing Genetic Variability

2. **Mesospecies**
   - Range stable - subspecies and individuals abundant

3. **Euspecies**
   - Range stable - individuals fairly abundant, few or no subspecies

4. **Telospecies**
   - Reduction in range and numbers
Speciation in Australian Treecreepers

- Treecreeper species populations are isolated by large regions of inhospitable habitat (desert and dry areas).
- These geographical barriers (circles below) are thought to have contributed to their speciation.

Circles denote physical barriers to expansion of the species range

Zone of sympatry due to secondary range expansion

Plumage Colour Key

- Black
- Brown
- Rufous

Set 7: Evolution
Factors Affecting Distribution

Changes in Sea Level
- Oscillations between periods of climatic cooling (ice ages) and periods of warming (interglacials) cause sea levels to rise and fall.

Ice Ages
During ice ages, vast amounts of sea water are lost as snowfall on the land and polar caps. This has the effect of causing a large drop in sea level (60 m). Areas previously isolated by water may develop land bridges, allowing species to move from one region to another.

Warm Periods
In interglacial periods species may again be isolated by a rise in sea level. Separated on either side of a now submerged land bridges, they may evolve in response to very different selection pressures.

Continental Drift
- The crust of the Earth is in constant motion, moving whole continents and sea floors.
- The movement of continents, sometimes joining together and at other times separating, has had a powerful effect on the distribution of organisms.
Changes in Sea Level

Falls in sea level or during ice ages create important land bridges while rises in sea level during interglacial periods create geographical barriers:

Warm Interglacial period

Populations on the mainland and the offshore island are separated by the physical barrier of the sea.

Mainland populations

Island populations

Present-day sea level

These isolated populations may be subjected to different natural selection pressures and may ultimately give rise to separate species.

Ice Age

Snow and ice fields

Mainland and island communities remix

Sea level drops by 60 metres (200 feet)

After the sea bed has been exposed for thousands of years, recolonisation by terrestrial plants and animals may occur, allowing dispersal of island species to the mainland and vice versa.
Continental Drift 1

- The movement of continents moved whole assemblages of plants and animals across the surface of the Earth.
- As well as creating geographical barriers in the form of oceans, it brought new combinations of species together.

### Late Palaeozoic

- 250 million years ago
- The continents formed a single landmass; dinosaurs and mammal ancestors roamed the earth.

### Palaeocene – Mid Eocene

- 65-46 million years ago
- Most continents were separated, North America and Europe joined; mammals underwent adaptive radiation into many forms.

### Late Eocene

- 46-38 million years ago
- Europe split away from North America and joined Asia. India was still an island, with South America joined to Antarctica.
The map of the present day world below shows the continents and islands that once comprised the supercontinent of **Gondwana**, and evidence supporting how they once formed this single landmass.
Continental Drift 3

The map below shows how the continents and islands that once comprised the supercontinent of Gondwana may be fitted together to form the single landmass.
New Zealand as a Natural Laboratory for Evolution

- The islands of New Zealand in the South Pacific ocean provide an excellent case study to examine the effects of geophysical events on evolutionary processes.
- Consisting of two large islands and a smaller one to the south, the group of islands were subjected to changes in sea level as ice ages came and went.
- During the ice ages, the drop in sea level caused the islands to be united as a single land mass.
- During periods of climate warming (interglacials), the sea level rose to create more islands and archipelagos, particularly in the northern part of New Zealand.
Interglacials in New Zealand

- During the warm interglacials, the sea level rose to create more islands and archipelagos in the northern part of New Zealand.
- Adjacent terrestrial populations which were once linked, became isolated from each other.
- This isolation of gene pools may have assisted in the process of speciation in New Zealand.
Ice Ages in New Zealand

- During the colder climates of the ice ages, the sea levels fell, exposing a larger land mass.
- Islands that were once separated were then connected by exposed sea bed.

New Zealand
During an Ice Age

- Woody Vegetation
- Subalpine Grassland
- Steppe Loess Zone (Grassland)
- Glaciers and Snow

Sea level 60 m below present level, revealing large areas of sea bed

New Zealand Today

Puysegur Is.
Traps Is.
Three Kings Is.
Poor Knights Is.
Ranfurly Is.
Mernoo Is.
Three Kings Is.
Woody Vegetation

Set 7: Evolution
Speciation in New Zealand Stag Beetles

- Stag beetles shared a common ancestor more than 10 million years ago, before the Pliocene sea level rise.
- Rises in the sea level created island chains separated by straits (see map bottom left).
- The isolated populations formed distinct species.
- The present distribution of four species is shown below:

**Lissotes oconnori**
- Cape Maria van Diemen
- North Cape

**Lissotes mangonuiensis**
- A Staghorn Beetle (genus *Lissotes*)

**Lissotes planus**
- Whangarei

**Lissotes reticulatus**
- Auckland
- Zone of overlap (sympatric distribution)

New Zealand During the Pliocene
Speciation in New Zealand Flax Snails

- Flax snails, which are not very mobile, evolved in isolation in different regions of New Zealand during periods of raised sea level (e.g. Pliocene).
- The isolated populations formed three distinct species and have evolved adaptations to particular habitats.

**Map of New Zealand During the Pliocene**

- **Placostylus bollonsi**
- **Placostylus ambagiosus**
- **Placostylus hongii**

New Zealand During the Pliocene

- Auckland
- Whangarei
- Three Kings Is.
- North Cape
- Northland Island
- Poor Knights Is.
Phylogeny and Taxonomy

- The evolutionary history of a group of related species is called **phylogeny**.
- Reconstructing phylogenies involves identifying and classifying species to show their evolutionary relatedness: a discipline (or area of study) called **taxonomy**.
- Similarity of form due to a shared ancestry is called **homology**.

**EXAMPLE:** Classification and Phylogeny of Order Carnivora.

![Diagram showing the classification and phylogeny of various carnivores, including Canis, Vuples, Felis, Panthera, and Acinonyx, categorized under Canidae and Felidae families under the order Carnivora.](image)

**NOTE:** This is a simplified diagram - there are additional families, genera, and species not represented here.
Convergent Evolution

- Not all similarity is inherited from a common ancestor:
  Species from different evolutionary branches may resemble each other if they have similar ecological roles.
  This is called **convergent** evolution.
- Similarity due to convergence is not a basis for including species in the same taxonomic group.
  EXAMPLE: The swimming carnivore niche.
- This niche was exploited by a number of unrelated vertebrate groups at different times in the history of life.
- The selection pressures of this niche produced fins or flippers and a streamlined body shape for rapid movement through the water.

**EXAMPLES:**

- **Reptile:** Icthyosaur (extinct)
- **Fish:** Shark
- **Mammal:** Dolphin
- **Bird:** Penguin
Convergent Evolution in Mammals

- Marsupial and placental mammals have evolved separately to occupy similar niches – they are ecological equivalents.

### Marsupial Mammals
- Australia
  - Wombat
  - Marsupial mole
  - Marsupial mouse
  - Tasmanian wolf
  - Long-eared bandicoot

### Placental Mammals
- North America
  - Wood chuck
  - Flying squirrel
  - Mole
  - Mouse
  - Wolf
  - Rabbit

Set 7: Evolution
Divergent Evolution

The diversification of an ancestral group into two or more species in different habitats is called **divergent evolution**.

When divergent evolution involves the formation of a large number of species to occupy different niches this is called an **adaptive radiation**.

A hypothetical family tree showing divergence from common ancestors on two occasions:

- **Species P**
- **Species H**

**Changes in the genetic make-up of the two species**

**Species B**

- **Speciation by splitting**
- Genetic changes accumulate to form a new species

**Species W**

- Extinction
- **Speciation by budding**

**Species D**

- Little genetic change - species remains relatively unchanged

**Common Ancestor**
Gradualism

Gradualism assumes that populations slowly diverge from one another by accumulating adaptive characteristics in response to different selective pressures.

If species evolve by gradualism there should be transitional forms seen in the fossil record, as with the evolution of the horse.

Set 7: Evolution
Punctuated Equilibrium

- There is abundant evidence in the fossil record that, instead of gradual change, species stayed much the same for long periods (stasis) and had short bursts of evolution that produced new species quite rapidly.
- According to the punctuated equilibrium theory, most of a species’ existence is spent in stasis and little time is spent in active evolutionary change.

New species ‘bud off’ from the parent species and undergo rapid change, followed by a long period of stability.

Set 7: Evolution
**Macroevolution**

- Macroevolution refers to evolutionary changes above the level of the species: changes in genera or orders.
- Macroevolution is concerned with changes in the kinds of species over evolutionary time and includes:
  1. The origin of unusual features (evolutionary novelties).
  2. The origin of evolutionary trends (e.g. increased brain size in primates).
  3. Adaptive radiation (a form of divergent evolution).
  4. Extinction.

Example of evolutionary trend: **brain size in hominids**

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**Increasing Brain Size**

- *A. afarensis*: 450cc
- *H. habilis*: 675cc
- Neanderthal: 1400cc
- *H. sapiens*: 1800cc
A change in the basic design of an organism can produce a unique feature.

EXAMPLES:
1. Flowers of angiosperms.
2. Feathers of birds.
3. Wings of insects.

These new structures or **preadaptations** are usually variations of some existing structure already in use for some other function.

EXAMPLES:
1. The **feathers** of birds have evolved from the **scales** of reptiles.
2. The bones of the middle ear in mammals have been modified from equivalent bones of the reptilian jaw.

**Novel adaptations** are thought to arise through changes to regulatory genes. This can result in changes to body structure, or to the rate or timing of development.
Adaptive Radiation

- When an organism develops a new adaptive feature, a new niche may become available to it.
- Once new niches are made available, an ancestral species can **radiate** from its point of origin and new species develop to exploit different habitats.
- Adaptive radiation is more common in periods of major environmental change e.g. cooling climates. These changes may be the driving force for adaptive radiation or they may have an indirect effect by increasing the extinction rate.

**EXAMPLE**: The radiation of the mammals occurred after the extinction of the dinosaurs, which has made niches available for exploitation.

Arboreal Herbivore Niche

Marine Predator Niche

Underground Herbivore Niche

Terrestrial Predator Niche

Freshwater Predator Niche

Browsing/Grazing Niche

Flying Predator/Frugivore Niche

**Megazostrodon** - an early mammal ancestor

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**Set 7: Evolution**
The mammals have diversified widely, from an ancestral shrew-like form, into many different niches:

**Set 7: Evolution**

**Adaptive Radiation in Mammals**

- Sea-cows
- Elephants
- Hyraxes
- Even-toed ungulates
- Aardvark
- Odd-toed ungulates
- Whales & dolphins
- Carnivores
- Seals
- Insectivores
- Bats
- Colugos
- Primates
- Rodents
- Hares, rabbits, pangolins
- Anteaters, sloths
- Marsupials
- Monotremes

**Geological Time Scale**

- Palaeocene
- Eocene
- Oligocene
- Miocene
- Pliocene
- Pleistocene
- Holocene

**mya**

- 200
- 134
- 65
- 53
- 37
- 25
- 5
- 1.8
- 0.01

**Early Mammals**

**Placentals Diverge**
The Diversity of Mammalian Orders

Modern mammals are represented by 17 orders:

- Primates
- Edentata
- Chiroptera
- Carnivora
- Rodentia
- Cetacea
- Tubulidentata
- Artiodactyla
- Perissodactyla
- Probiscidea
- Lagomorpha
- Pinnipedia
- Dermoptera
- Insectivora
- Sirenia
- Pholidota
- Hyracoidea

Set 7: Evolution
Divergent Evolution of the Ratites

The ratites are an ancient group of birds that have evolved from one ancestor and lost their powers of flight early in their evolutionary development.

Their distribution can be explained by continental drift following the break-up of Gondwana.
Divergence and Radiation of the Ratites

Mesozoic Era

Birds evolved from a dinosaur ancestor about 150 million years ago

Ratites diverge from the line to the rest of the birds about 100 million years ago

Cenozoic Era

Fossil evidence suggests that ratite ancestors possessed a keeled breastbone and an archaic palate (roof of mouth)

RATITES

All other living birds

Moa 1: Anomalopteryx
Moa 2: Pachyornis
Moa 3: Dinornis
Moa 4: Megalapteryx
Little Spotted Kiwi
Great Spotted Kiwi
Brown Kiwi
Emu
Cassowary
Ostrich
Elephantbird
Rhea 1
Rhea 2
Tinamou (can fly)

Letters indicate common ancestors

A

Set 7: Evolution

OHT 83
Extinction

- Most species that have ever lived are now extinct.
- Entire lineages that were once dominant have now disappeared or have dwindled in numbers as other radiations have flourished.
- Often, the extinction of one group has allowed another to undergo extensive radiation into free niches: large scale species changes are probably opportunistic events.

*Radiations may follow extinctions but are rarely the cause of extinctions.*

Background Rates of Extinction

- A background rate of extinction describes the steady rate of species extinction that is a natural feature of evolving taxonomic groups.
- The causes of such extinctions vary depending on the species. In general, larger and more complex organisms have higher rates of background extinction than simpler organisms.

Mass Extinction

- Superimposed on average rates of background extinction are five events in the Earth’s history when the rate of extinction rose markedly. These are called **mass extinctions**.
- Mass extinctions refer to an abrupt increase in extinction rates affecting huge numbers of species at the same time. During these episodes the diversity of major groups declines.
Background Extinction

- Studies of the fossil record have revealed that each taxonomic group has species with a characteristic “duration of existence” before becoming extinct.
- This provides the average background extinction rate for the taxonomic group.

### Examples of the Estimated Average Durations of Species

<table>
<thead>
<tr>
<th>Taxonomic Group</th>
<th>Species Duration (millions of years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mosses and Liverworts</td>
<td>20 +</td>
</tr>
<tr>
<td>Higher Plants</td>
<td>8-20 +</td>
</tr>
<tr>
<td>Bivalves</td>
<td>11-14</td>
</tr>
<tr>
<td>Snails</td>
<td>10-13</td>
</tr>
<tr>
<td>Ammonites</td>
<td>1-15</td>
</tr>
<tr>
<td>Trilobites</td>
<td>1 +</td>
</tr>
<tr>
<td>Beetles</td>
<td>2 +</td>
</tr>
<tr>
<td>Freshwater Fishes</td>
<td>3</td>
</tr>
<tr>
<td>Snakes</td>
<td>2 +</td>
</tr>
<tr>
<td>Mammals</td>
<td>1-2 +</td>
</tr>
</tbody>
</table>

(After Stanley, 1985)
Global history has been characterised by five major extinction events and two of these have been intensively studied by palaeontologists:

- **The Permian Extinction** *(225 million years ago)*
  This extinction event marks the Palaeozoic-Mesozoic boundary
  – over 90% of marine species perished and probably many terrestrial ones also.

- **The Cretaceous Extinction** *(65 million years ago)*
  Marks the Mesozoic-Cenozoic boundary and exterminated more than half the marine species and many families of terrestrial plants and animals, including nearly all the dinosaur species (the birds may be dinosaur descendants!)
Mass extinctions are the result of more widespread and possibly catastrophic events than those that affect individual species. The causes of mass extinctions are the topic of much heated debate among palaeontologists today.

Theories include:

1. Changes in **climate** due to continental drift (slow). **Sea level** changes caused by successive ice ages and interglacials are implicated in most cases (slow).
2. Dust from **volcanic activity** on a huge scale causing a cooling of the planet (faster).
3. **Asteroid/comet impact** causing a dust cloud and cooling effect (immediate).

The Permian extinctions occurred at about the time the continents merged to form the super-continent of Pangaea. This probably caused a major disturbance or destruction of many habitats, and altered the climate.

There are many more theories to account for the Cretaceous extinctions, but one is most promising:

- There is good evidence for an asteroid or comet strike at this time, which may have created a cloud of dust, blocking light and inducing a “nuclear winter” effect.
- A probable site for the impact crater lies just off the coast of the Yucatan Peninsula in Mexico.
Micro- vs Macroevolution

- The mechanisms of gene pool change and natural selection represent the modern synthesis of evolution.

- Many biologists believe that given enough time, small microevolutionary processes are sufficient to account for large evolutionary changes or macroevolution.

Over long periods of time (millions of years) new species will give rise to new genera, families, orders and phyla (the gradualist view).

- Other biologists believe (in the punctuated equilibrium view) that:
  1. While natural selection is the force behind permanent gene pool changes and “fine-tunes” organisms to their environment ..... 
  2. Most morphological change occurs during abrupt, chance speciation events and once in existence, species then change very little.

- However, the debate is not about whether or not evolution occurs. It is only about the relative importance of different evolutionary mechanisms.
**Forces Operating in Evolution 1**

Various “forces” or phenomenon have a part to play in the evolutionary process:

- At the **molecular level**:
  - Point mutations
  - Control of gene expression
  - Rate of protein synthesis

- At the **chromosomal level**:
  - Crossing over
  - Block mutations
  - Polyploidy
  - Aneuploidy
  - Independent assortment
  - Recombination

- At the **cellular level**:
  - Gamete viability
  - Fertilisation
  - Genotype expression

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**Set 7: Evolution**
Forces Operating in Evolution 2

At the **organism level:**
- Environmental modification of phenotype
- Reproductive success
- Selection pressures
- 'Fitness' of the phenotype

At the **population level:**
- Genetic drift and population size
- Natural selection altering gene frequencies
- Mate selection
- Intraspecific competition
- Founder effect
- Immigration/emigration (gene flow)
- Population bottlenecks

At the **species level:**
- Geographical barriers
- Reproductive isolation (prezygotic and postzygotic)
- Selection pressures
- Interspecific competition