

Demonstrate understanding of evolutionary processes leading to speciation

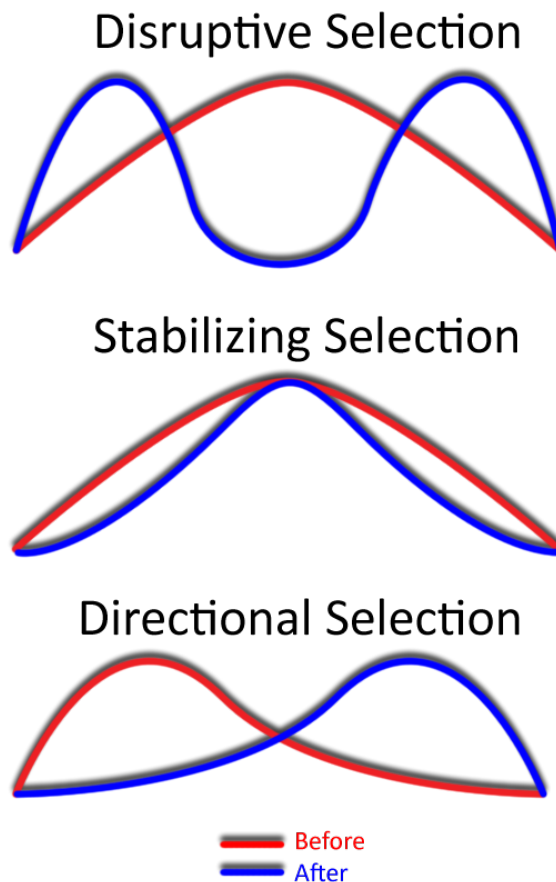
Recap of Level 2 concepts:

- Evolution is the accumulation of changes over time and it ensures that organisms are well-adapted to their environment.
- Species: a species is a group of individuals that is able to interbreed and produce fertile offspring.
- Speciation is the development of one or more species from an existing species.
- Mutations are changes in the genotype of an organism that may be passed on to offspring if they occur in the gametic cells (sperm, egg, ova or pollen). They will not be passed on to future generations if they occur in the somatic cells (non-sex cells)
- Mutations can be harmful, silent or beneficial. If they are harmful they will be selected against during natural selection and so are not likely to become established in the gene pool. But if they are silent or beneficial they may offer the organism a selective advantage and result in an increased presence in the gene pool.
- The total set of genes in a population at a specific time is referred to as the gene pool.
- All alleles have been produced by mutation as it is the only way of creating new alleles.
- There are five ways that gene pools can change, i.e. microevolution can occur. They are: genetic drift, gene flow, mutation, non-random mating and natural selection.
- Microevolution is the slow change in the gene pool over time due to natural selection.
- Gene flow refers to alleles being passed between populations by migration: immigration is the movement of alleles into a population and emigration is the movement of alleles out of the population. Immigration can increase genetic biodiversity as it adds alleles to the population while emigration lowers genetic biodiversity as it removes alleles from the population.
- Genetic drift is the change in allele frequency due to chance and not natural selection. It is most important in small populations, as the death of a few individuals can cause a major change in the gene pool in one generation.
- Founder effect - small numbers of an established population become isolated from the original population e.g. a small number of individuals colonising an island. These founders will carry with them only a portion of the total gene pool found in the original population. What alleles are carried to the new population is a matter of chance. Genetic biodiversity is reduced and some alleles may be absent or more common than in the original population.
- Bottleneck effect – this occurs when a population becomes small (due to things such as earthquakes, floods, fires or humans hunting) and then expands; the new gene pool will reflect the alleles that were present in the bottleneck population. This is an important effect when discussing endangered species.
- Variation by the mixing of existing alleles is produced by crossing over (recombination), independent assortment, segregation and random fertilisation during sexual reproduction.

Darwin's theory of evolution by natural selection:

- Variation of alleles exists within the population
- The organisms are exposed to a selective pressure such as a changing environment
- Those with favourable phenotypes are more likely to survive and reproduce while those with less favourable phenotypes have less chance of surviving and reproducing. "survival of the fittest"
- Each generation will be better adapted to the current environment.
- Types of natural selection:
 - Stabilising selects against the two extremes and favours the middle

- Directional selects against one of the extremes
- Disruptive selects against the middle and favours the two extremes, this can lead to speciation

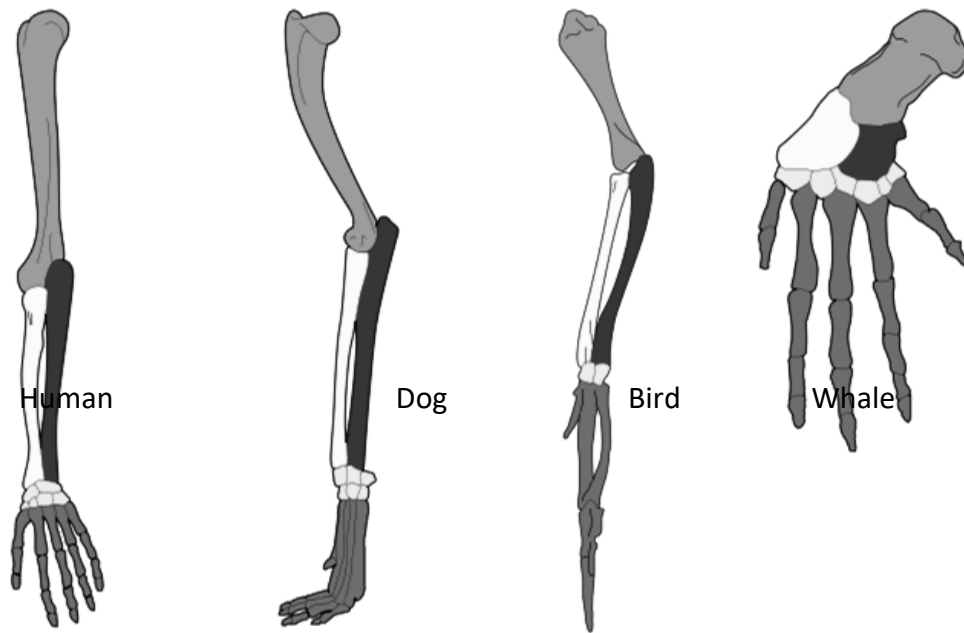


Evidence for evolution:

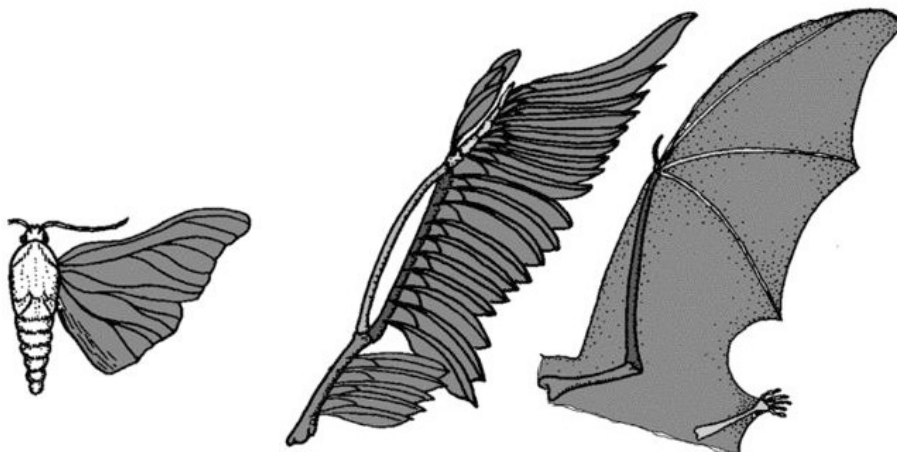
- Fossils (palaeontology) - the study of fossils compared to present day species.



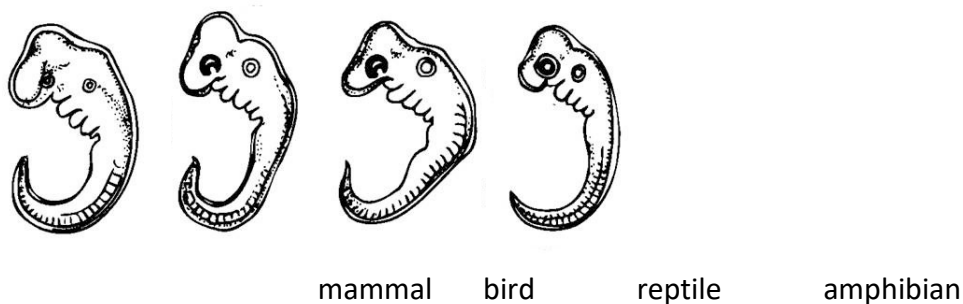
- **Comparative anatomy**
 - **Homologous structures** have the same origins but have evolved different functions e.g. The forelimb bones of frogs, crocodiles, birds, humans, whales, bats and all other vertebrates are the same and are arranged in a common pattern, although the limbs perform very different functions in the different animals. Homologous structures also show us that evolution works primarily by modifying pre-existing structures.



- **Analogous structures** have different origins but have evolved similar functions e.g. wing of insect bird and bat etc.



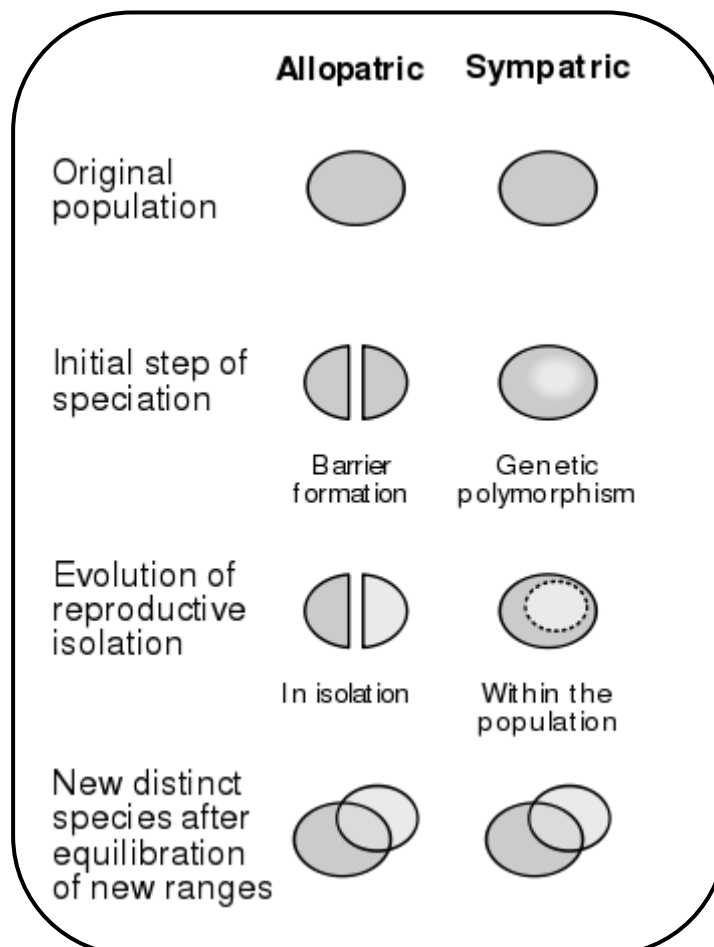
- Embryology is the study of the embryological development; the more similar they are the less time has passed since the species diverged.



- Biogeographical evidence looks at the geographical origins and how the species are now distribution.
- Biochemical and biotechnological evidence- this uses DNA and proteins similarities and differences to determine relativeness of organisms.

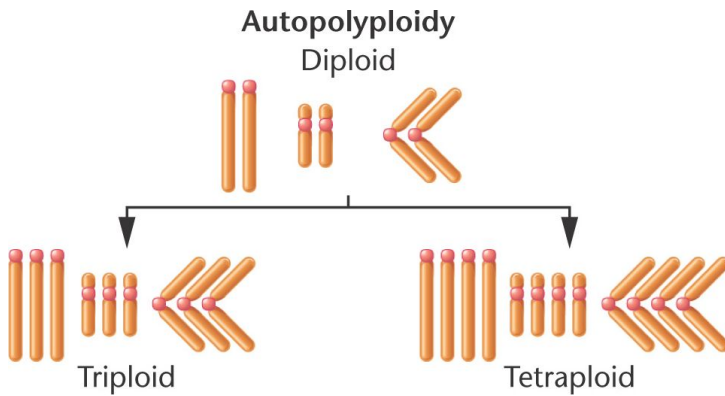
Speciation:

- The process by which one species gives rise to two or more new species is called speciation. In nearly all cases speciation requires geographical separation of the original population to form allopatric populations.
- **Steps of speciation:**
 - A geographical barrier forms
 - Different selective pressures in the separate environments cause the populations to diverge genetically (possible subspecies)
 - Postzygotic isolating mechanisms occur due to mutations and the creation of new alleles.
- **Allopatric speciation:** (different origins). Selection would favour those individuals which mate with their own kind. Speciation occurs in different geographical areas.
 - Gene flow is prevented by islands, glaciers etc.
 - Isolated populations subjected to different selective pressures and undergo natural selection
 - Accumulated differences in the two gene pools result in reproductive isolation even if they come back together.
- **Sympatric speciation:** (same origin)
 - Speciation occurs in the same geographical area and is not common in animals.
 - Gene flow prevented by mechanisms not geographical e.g. behaviours such as when active etc.

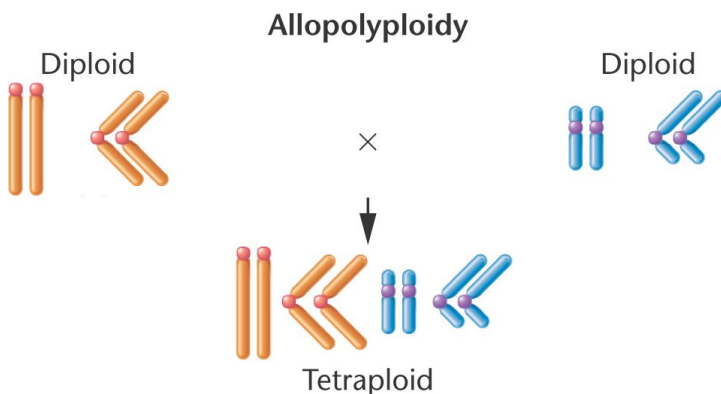


• **Instantaneous speciation:**

- This is a special type of sympatric speciation which occurs by polyploidy (containing 3 or more sets of homologous chromosomes: $3n$, $4n$ etc) resulting in a new species being formed in one generation. Rare in most animal groups but a common origin of new species in plants. Many polyploids show increased vigour and have ability to cope better with extreme climatic conditions.
- **Autopolyploidy** develops when all sets of chromosomes come from the same ancestral species.

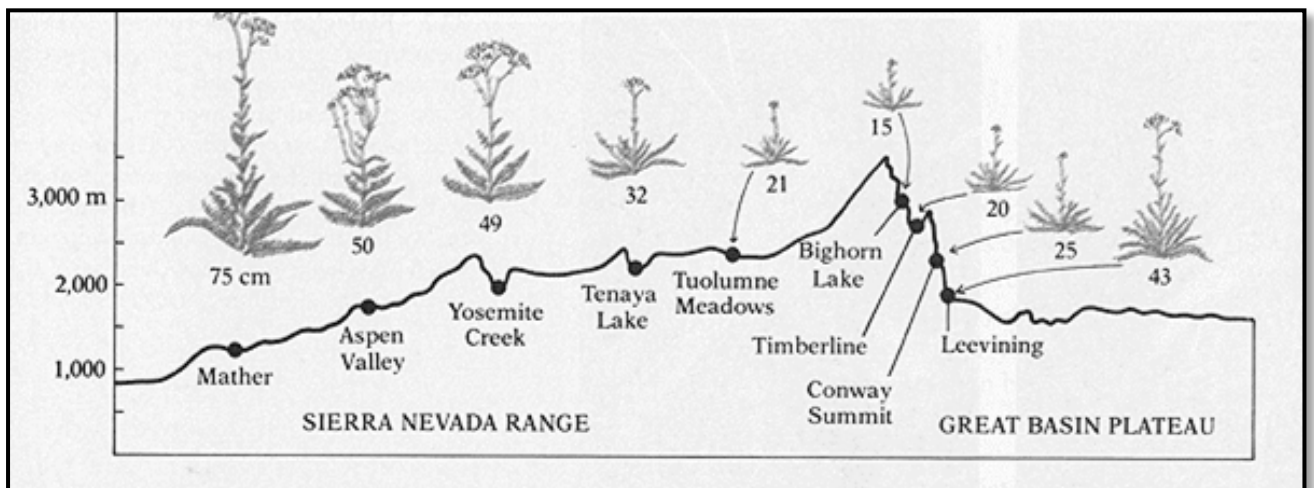


- **Allopolyploidy** develops when the sets of chromosomes originate from 2 or more ancestral species.



Groups within a species:

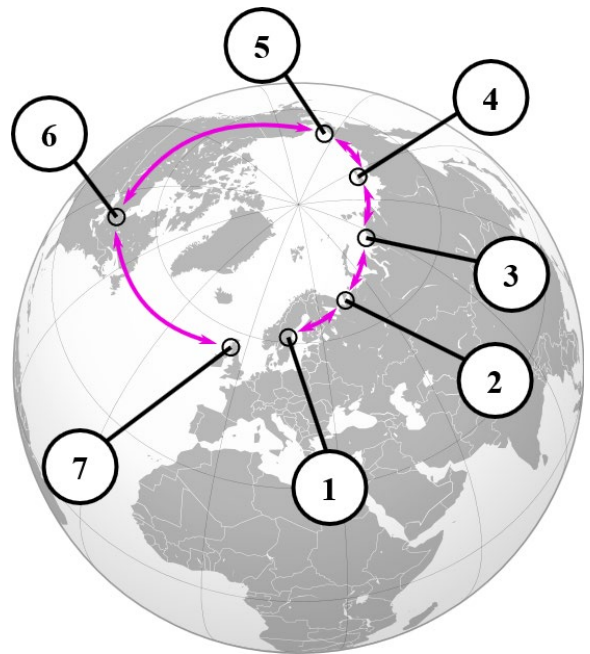
- **Cline** – species which show a gradual change in phenotypes over a geographical area e.g. the gradual change in the tree sizes for the same species as you move along the coast or up the mountain.



- Ring species – this is a special type of cline which has a circular or looped geographical distribution. Populations beside each others can interbreed but if the two ends of the cline overlap they cannot interbreed.

The **Larus gulls** interbreed in a ring around the arctic.

- 1: *Larus argentatus argentatus*,
- 2: *Larus fuscus (sensu stricto)*,
- 3: *Larus fuscus heuglini*,
- 4: *Larus argentatus birulai*,
- 5: *Larus argentatus vegae*,
- 6: *Larus argentatus smithsonianus*,
- 7: *Larus argentatus argenteus*



- Deme – these are local units of any one species. They often have some genetic characteristic which sets them apart from other nearby populations. The local populations have limited gene flow between them and overtime their gene flow may diverge.

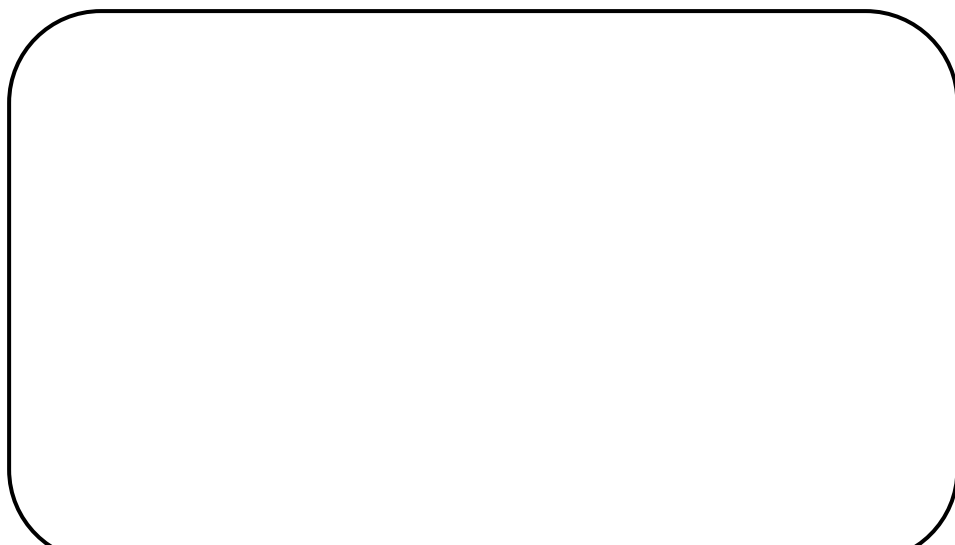
Reproductive isolating mechanisms.

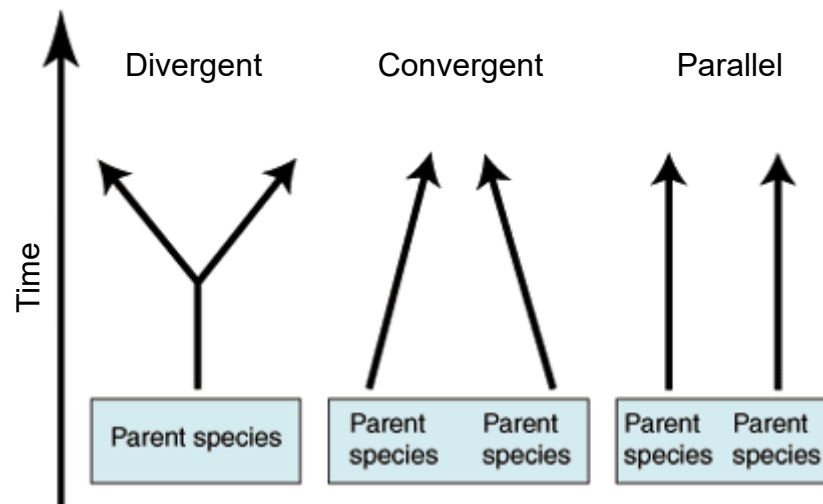
- These are any mechanism or factor which prevents successful reproduction between 2 species (prevents the gene flow between 2 gene pools).
- These isolating mechanisms are usually broken down into two categories- **pre-zygotic** (before fertilization) and **post-zygotic** (after fertilization)
- **Pre-zygotic**
 - Prevents gene flow between the 2 gene pools before fertilization.
 - Geographical isolation e.g. oceans, mountain ridges, rivers etc.
 - Temporal (timing .of the activity or reproduction between the 2 gene pools is different) e.g. active at different times of the day or mate at slightly different times of the year.
 - Ethological (behavioural differences) e.g. the two different species do not recognise each other's courtship and mating behaviour so are not attracted to each other.

- Ecological (different ecological niches) e.g. in the same geographical area the 2 species may occupy slightly different ecological niches so do not come into direct contact with each other.
- Structural (anatomical differences) e.g. the animals sexual organs are not shaped to “fit” together preventing mating. In plants it maybe the shape of the flowers determine which organisms can act as the pollinator.
- Gamete incompatibility (biochemical differences which prevent the zygote from forming as the sperm / pollen is not attracted to the chemicals produced by the egg.
- **Post-zygotic**
 - These are mechanisms which occur after the zygote has formed
 - Hybrid inviability – the fertilised egg does not develop as the chromosomal incompatibility leads to developmental problems resulting in a very low chance of the offspring surviving.
 - Hybrid sterility – the organism reaches maturity but is sterile e.g. mule
 - Hybrid breakdown – hybrid (F1) is fertile but their offspring (F2) are sterile

Patterns of evolution

- **Convergent evolution** this occurs when two **unrelated species** that evolve independently of each other develop similar adaptations due to similar selective pressures e.g. sharks and dolphins, bats and birds
Key point: they have NO common ancestor but due to natural selection and the same types of selective pressures they have evolved independently similar adaptations.
- **Divergent evolution** occurs when a **common ancestor** diverges (splits) into two species due to different ecological niches / selective pressures resulting in natural selection favouring different phenotypes resulting in two species over time.
Often populations become isolate from the main gene pool (founder effect) with first geographical isolation occurring then over time other reproductive isolating mechanisms occur resulting in new species forming.
- **Adaptive radiation** is 'the evolution of an ancestral species, which was adapted to a particular way of life, into many diverse species, each adapted to a different habitat'. Adaptive radiation is rapid speciation into many different forms. Such rapid speciation is likely to occur after an extinction event which creates many vacant ecological niches, so organisms evolve to fill them e.g. climate change has changed sea levels many times during the Earth's history, which has produced new environments to colonise resulting in adaptive radiation occurring.
- **Parallel evolution** occurs when a common ancestor that diverged but due to changing selecting pressures they later developed similar features e.g. the loss of wings on off shore islands by birds.





- **Co-evolution** When different groups of organisms have close ecological relationships, they have a strong effect on each other's evolution, e.g. prey animals and plants have evolved many different and effective ways of avoiding being eaten by animals and at the same time the predators and grazers have evolved different ways of making sure they get food.

We say that predators and prey, or grazers and plants, co-evolve.

Some examples of co-evolution include:

- Plant – herbivores
- Plant – pollinators
- Predator – prey
- Parasites – host
- Mimics – models



Rate of evolutionary change

There are two models used to discuss the rate of evolutionary change. Both models have evidence to support them; one model does not contradict the other.

- **Gradualism**. This states that evolutionary processes proceed slowly but continuously and eventually the accumulation of changes result in speciation occurring. Over a long time period this gradual change would produce a phylogenetic tree like that shown below.
- **Punctuated equilibrium**. This states that there are long periods of very little evolutionary change (stasis) interrupted by short bursts of rapid speciation. These rapid changes may be triggered by sudden changes in the environment.

Remember with both of these models, genetic drift, founder effect, sexual reproduction and natural selection cause the change.