SPECIATION

Content Statements:

A4.1.8	Differences and similarities between sympatric and allopatric speciation
A4.1.9	Adaptive radiation as a source of biodiversity
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A4.1.11	Abrupt speciation in plants by hybridization and polyploidy
A4.1.12	Difficulties applying the biological species concept to asexually reproducing species and to bacteria that have horizontal gene transfer
A4.1.13	Chromosome number as a shared trait within a species
A4.1.14	Engagement with local plant or animal species to develop a dichotomous key
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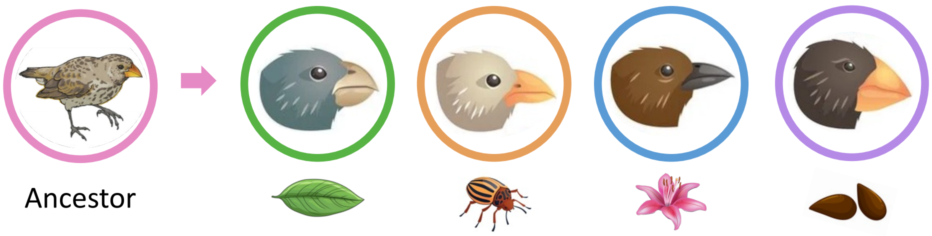
GENETIC DIVERSITY

Mutations and **meiotic recombination** function to generate genetic variation within a sexually reproducing population – no two individuals should be identical in all of their traits. Populations typically tend to display **continuous variation**, whereby the phenotypic expression of a characteristic follows a normal (bell-shaped) distribution curve. External forces (such as environmental selection pressures) can cause a given population to genetically diverge and evolve into different species (speciation). **Adaptive radiation** describes the rapid evolutionary diversification of a single ancestral line. It occurs when members of a single species occupy a variety of distinct niches with different environmental conditions. Members evolve different adaptations in response to the different selection pressures. Adaptive radiation will allow closely related species to coexist without competing, thereby increasing biodiversity in ecosystems where there are vacant niches available.



Darwin's finches evolved different shaped beaks via adaptive radiation to suit the different habitats / diets

ISOLATION BARRIERS

Reproductive isolation occurs when barriers prevent populations from interbreeding. Over time, genetic differences will accumulate, leading to eventual speciation. There are two main types of isolation barriers:

Pre-zygotic barriers occur before fertilisation (no interbreeding means that no offspring can be produced).

- *Geographic isolation* occurs when distinct populations occupy different habitats (e.g. lions and tigers)
- *Behavioural isolation* occurs when populations exhibit different courtship rituals (e.g. bird mating calls)
- *Temporal isolation* occurs when two populations differ in their reproductive cycles (e.g. coral spawning)

Post-zygotic barriers occur after fertilisation (offspring produced but are either not viable or are infertile).

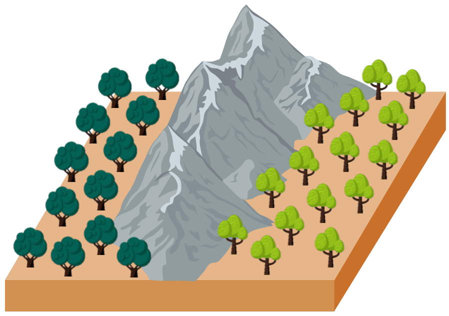
- *Hybrid inviability* occurs when offspring fail to develop to maturity (e.g. tadpoles fail to metamorphose)
- *Hybrid infertility* occurs when hybrid offspring are viable but cannot produce gametes (e.g. sterile mule)

TYPES OF SPECIATION

Speciation involves the formation of a new species from a pre-existing species (via divergent evolution). It occurs when two populations become **reproductively isolated** (no gene flow). The accumulation of genetic differences causes the populations to gradually diverge to the point where they can no longer interbreed.

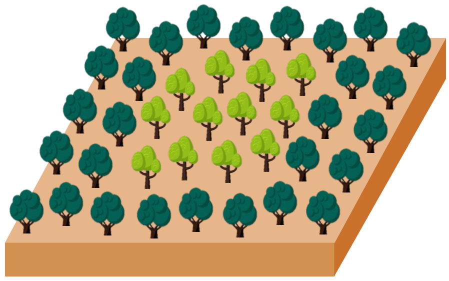
Allopatric Speciation

Allopatric speciation occurs when a **geographical barrier** physically separates populations of an ancestral species. The populations will evolve along separate pathways as a result of cumulative mutation, genetic drift and natural selection. A specific example of this type of speciation is the evolution of bonobos and chimpanzees as a result of the separation of populations by the flooding of the Congo River.



Sympatric Speciation

Sympatric speciation involves the divergence of species within the same geographical area (i.e. **without a physical barrier**). Sympatric speciation can occur as a consequence of temporal or behavioural isolation (e.g. separate breeding cycles or different mating rituals). A specific example of this type of speciation includes the evolution of unique species of *Howea* trees due to different flowering times.

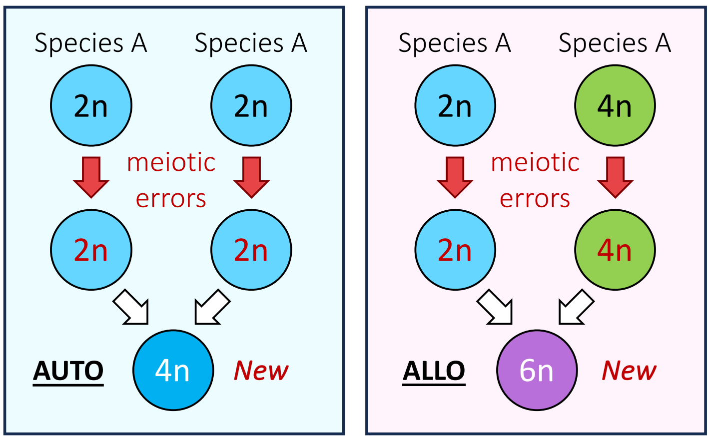


ABRUPT SPECIATION

Speciation is typically a slow process, with genetic divergence occurring gradually as a consequence of the accumulation of random mutations. However, speciation can occur abruptly if errors in gamete formation and fusion lead to offspring becoming genetically incompatible with other members of the original species.

Polyploidy is a condition in which organisms have more than two complete sets of chromosomes in cells – via either autopolyploidy or allopolyploidy.

- **Autopolyploidy** involves a polyploid offspring being derived from a **single** parental species (caused by *meiotic errors in cytokinesis* – left)
- **Allopolyploidy** involves a polyploid offspring forming from **two distinct** parental species (due to the process of *hybridisation* – right)



Because polyploid organisms require other compatible polyploids to form a separate species, it is more commonly seen in plants (polyploidy is not a common phenomenon). Monecious plants can potentially **self-pollinate** and any polyploid offspring may be able to **reproduce asexually** via *vegetative propagation*.

Polyploid crops typically grow larger in size and demonstrate improved longevity and disease resistance due to **hybrid vigour** – where the combined action of additional alleles results in more robust phenotypes and the masking of deleterious recessive conditions. An example of a polyploid crop that demonstrates hybrid vigour is the **knotweed** (genus *Fallopia*), which is known for its rapid growth rate and general invasiveness.

- Giant knotweed = 4n (tetraploid)
- Japanese knotweed = 8n (octoploid)
- Bohemian knotweed = 6n (hexaploid)
- Hybrid knotweed = 10n (decaploid)

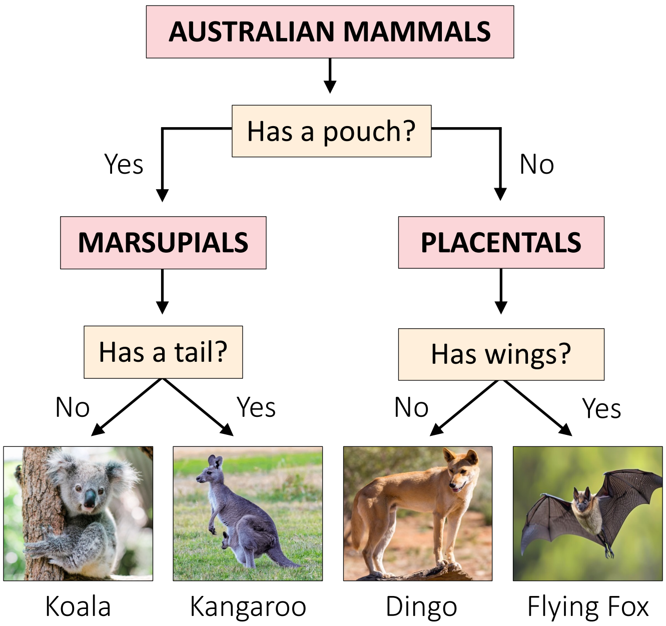
SPECIES CAVEATS

Historically, organisms were classified into species based on shared morphological characteristics. However, this did not account for the occurrence of analogous structures and was further limited by the gradations of phenotypes that existed within populations as a consequence of genetic variation. As a result, a **biological species concept** was introduced whereby a species was defined according to the capacity to interbreed and produce fertile, viable offspring. This requires members of a species to be genetically compatible, meaning that **chromosome number** is a shared trait in a species (cross-breeding won't produce functional gametes).

There are numerous difficulties that exist when applying the biological species concept universally. Bacteria **reproduce asexually** (via binary fission), so genetic compatibility of bacterial strains cannot be established. Additionally, bacteria can exchange plasmids (via **horizontal gene transfer**), so genetic information can be shared without producing any offspring. Hence, bacteria are classified based on other criteria (e.g. shape).

DICHOTOMOUS KEYS

A dichotomous key is a method of identification whereby groups of organisms are divided into **two groups** repeatedly. With each sequential division, more information is revealed about the specific characteristics of an organism. When it no longer shares its totality of features with another organism, it has been identified. When using dichotomous keys, it is important to use **immutable features** (e.g. size and colouration changes between individuals and across lifetimes). Physical structures and essential processes are better identifiers. Dichotomous keys can be shown as branching flowcharts or as paired statements in a numbered sequence.



1. Does it lay eggs?	
No	Go to 2
Yes	Go to 5
2. Is there a pouch?	
No	Go to 4
Yes	Go to 3
3. Does it have a tail?	
No	Koala
Yes	Kangaroo

4. Are there wings?	
No	Dingo
Yes	Bat
5. Are feet webbed?	
No	Echidna
Yes	Platypus

Australian Animal Dichotomous Key
(paired statements)

DNA BARCODING

DNA barcodes are short sequences of DNA that can be used for the identification of species. The sequences from which the DNA barcodes are derived are commonly taken from mitochondrial DNA in eukaryotes and ribosomal RNA in prokaryotes. The barcodes are compiled into only databases that function as a reference library (a database can contain over a million barcodes). A good DNA barcode is short in length (< 600 bp) and consists of a unique identification sequence and a conserved flanking sequence (to allow for the use of universal primers when amplifying the DNA). Scientists use DNA barcoding of **environmental DNA** (eDNA) to monitor the biodiversity of a habitat. Environmental DNA describes the genetic material released by an organism into its surroundings (in soil, water, faeces, etc.). The eDNA can be used to identify the presence of a species in the environment, without the need for direct observation or any invasive tracking methods.