**Sub-strand 4.4 Speciation**

**Key Learning Outcome:** Students are able to demonstrate understanding of the different types of speciation, the different reproductive isolating mechanisms and the impact of speciation on diversity:

* allopatric, sympatric, instant (polyploidy) speciation.
* Reproductive isolating mechanisms:
* pre-mating (pre-zygotic) – geographical, ecological, behavioural, structural, temporal.
* post-mating (post-zygotic) – hybrid inviable, hybrid sterile, hybrid breakdown.

**Lesson 1: Speciation**

**The specific learning outcomes (SLO) targeted in this activity are provided below:**

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| **SLO#** | **Specific Learning Outcomes:** Students are able to | **Skill level** | **SLO code** | **Achieved**  **(Yes / No)** |
| 1 | Define allopatric speciation | 1 | Bio4.4.1.1 |  |
| 1 | Define sympatric speciation | 1 | Bio4.4.1.1 |  |
| 1 | Define instant (polyploidy) speciation | 1 | Bio4.4.1.1 |  |
| 2 | Identify/State a feature or example of allopatric speciation in a given context | 1 | Bio4.4.1.2 |  |
| 2 | Identify/State a feature or example of sympatric speciation in a given context | 1 | Bio4.4.1.2 |  |
| 2 | Identify/State a feature or example of instant (polyploidy) speciation in a given context | 1 | Bio4.4.1.2 |  |
| 3 | Describe the features of allopatric speciation | 2 | Bio4.4.2.1 |  |
| 3 | Describe the features of sympatric speciation | 2 | Bio4.4.2.1 |  |
| 3 | Describe the features of instant (polyploidy) speciation | 2 | Bio4.4.2.1 |  |
| 4 | Describe the difference between allopatric and sympatric speciation | 2 | Bio4.4.2.2 |  |

**Notes:**

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| **Speciation**  **Speciation,** the formation of new species, results from populations becoming reproductively isolated; gene flow no longer occurs. Speciation may occur:   * gradually by the slow accumulation of small changes * instantly by changes in chromosome number through **polyploidy**.   There are several different types of speciation:  **Allopatric (Geographic) Speciation**   * Speciation mostly occurs after populations become separated by a geographic barrier. This type of speciation is called **allopatric speciation** (allo = different, patra = homeland). Populations may experience geographic isolation owing to such events as mountain building, changes in sea level, and changes in river courses. * Gene flow obviously stops once a population has become isolated from other populations. Any differences in natural selection pressures, such as the differing climatic conditions existing on each side of a mountain range, or on recently separated islands, can result in differences in allele frequencies in the gene pools. Eventually, the differences will accumulate to such an extent that, if individuals from the two populations do happen to meet, they can no longer interbreed – they have become separate species. * New Zealand is isolated country and many unique terrestrial species have developed by allopatric speciation. Animal and plant populations became isolated from their parent populations on other continents and were exposed to different selection pressures. The ability to fly was lost or reduced in many bird species because with no mammalian predators there was no selective advantage in continuing to fly. * Allopatric speciation can occur when populations become isolated on distant islands, e.g. New Zealand robins. * Once populations are effectively separated by geographic barriers, they may eventually become so different that they would not be able to interbreed if the physical barrier between the populations were removed. There can be no exchange between their gene pools. This is due to **reproductive isolating mechanisms**.   **Sympatric Speciation**   * It is possible for a new species to arise without geographical separation. This process is referred to as **sympatric speciation** (sym = together, patra = homeland).   Ecological speciation   * Sympatric speciation can occur through ecological isolating mechanisms. This can arise from a change in niche or lifestyle, where mating can be only between those who have adopted a new lifestyle (e.g. a new host plant, new food, etc.). Apart from restricting mating to within the population having taken up the new niche, existing genetic differences between them and other members of their species can rapidly become even greater differences, leading to a population being genetically isolated from the original population. If different populations are subject to greatly differing ecological conditions the resulting differences in selection pressures can lead to speciation. * Once populations are prevented from interbreeding, allele frequency differences will build up and the species will become increasingly different. Sympatric speciation is rarer than allopatric but it has been observed amongst cichlid fishes some insects.   **Instantaneous Speciation**  **Instantaneous speciation** refers to the sudden appearance of a new species. This occurs quite frequently in plants owing to polyploidy. A new plant acquires an extra set of chromosomes owing to the failure of chromosomes to separate at meiosis. The plant is reproductively isolated from the parent plant population, but it can reproduce by self-fertilisation. Eventually a viable population of sexually reproducing polyploidy plants is established. (Polyploidy is rare in animals as self-fertilisation is rare.)   * For example a tetraploid that produces diploid (2n) gametes cannot produce fertile offspring with normal plants that have haploid (n) gametes, because the offspring would have three sets of chromosomes. This would not allow normal pairing up to occur during meiosis. However, the tetraploid plants can breed amongst themselves to produce fertile offspring. This is because the offspring have four sets of chromosomes, all of which can pair up during meiosis. |

**Lesson Activities**

**Question One**

In your own words, define the following terms: (L1)(Bio4.4.1.1)

(i)Allopatric speciation: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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(ii) Sympatric speciation: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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(iii) Instant (polyploidy) speciation: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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**Question Two**

For the following, state the speciation feature. (L1)(Bio4.4.1.2)

a. Speciation occurs when a new species evolves from an existing species living in the same area.

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b. Speciation occurs when populations are separated by a geographical barrier.

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c. Speciation occurs when chromosomes fail to separate at meiosis, resulting in cells with one or more extra sets.

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**Question Three**

(i)Describe the features of allopatric speciation.

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(ii)Describe the features of sympatric speciation.

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(iii)Describe the features of instant (polyploidy) speciation.

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**Question Four**

Describe the difference between allopatric and sympatric speciation. **(L2)(Bio4.4.2.2)**

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**Lesson 2: Reproductive Isolating Mechanisms**

**The specific learning outcomes (SLO) targeted in this activity are provided below:**

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| --- | --- | --- | --- | --- |
| **SLO#** | **Specific Learning Outcomes:** Students are able to | **Skill level** | **SLO code** | **Achieved**  **(Yes / No)** |
| 5 | List the pre-mating (pre-zygotic) reproductive isolating mechanisms | 2 | Bio4.4.2.3 |  |
| 6 | Describe the features of each isolating mechanism | 2 | Bio4.4.2.4 |  |
| 7 | Explain why geographical isolation leads to reproductive isolation | 3 | Bio4.4.3.1 |  |
| 8 | Explain why ecological isolation leads to reproductive isolation | 3 | Bio4.4.3.2 |  |
| 9 | Explain why behavioural isolation leads to reproductive isolation | 3 | Bio4.4.3.3 |  |
| 10 | Explain why structural isolation leads to reproductive isolation | 3 | Bio4.4.3.4 |  |
| 11 | Explain why temporal isolation leads to reproductive isolation | 3 | Bio4.4.3.5 |  |

**Notes:**

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| **Reproductive Isolating Mechanisms**  Any factor that prevents two species from producing fertile hybrids contributes to **reproductive isolation.** **Reproductive isolating mechanisms** prevent populations of related species in the same area from interbreeding. Reproductive isolating mechanisms are important in preserving the uniqueness of a gene pool. They prevent the dilution effect of **gene flow** *into* the pool from other populations. Such gene flow may detract (reduce) from the good combinations already developed as a result of natural selection. Single barriers may not completely stop gene flow, so most species have more than one type of barrier. Geographical barriers are sometimes considered not to be isolating mechanisms because they are not part of the species’ biology. Such barriers often precede (come before) the development of other isolating mechanisms, which can operate before fertilization (**prezygotic**) or after fertilization (**postzygotic**). The features of the prezygotic isolating mechanisms (before fertilization) are: geographical isolation; temporal isolation; ecological isolation; gamete isolation; behavioural isolation; structural isolation.  **Prezygotic Isolating Mechanisms (Before-Fertilisation)**   |  |  | | --- | --- | | **Geographical (spatial) isolation**  Geographical isolation results from physical barriers such as: oceans, deserts, offshore islands, ice sheets, mountain ranges, etc., separating populations. If the populations come together again at a later stage, they are sufficiently different (as a result of different selection pressures in different environments, and/or possibly genetic drift) that they do not / are unable to breed. There are many examples of speciation occurring as a result of isolation by oceans or by geological changes in lake basins (e.g. the proliferation (increase) of cichlid fish species in Lake Victoria). The species of iguana from the Fiji Islands are now quite distinct from the Central and South American species from which they arose. When melting ice and subsequent rise in sea level separated New Zealand into the North and South Islands, two genetically isolated populations of birds were produced from one ancestral population, leading to speciation of kaka, *Nestor meridionalis,* in the north, and kea, *Nestor notabilis,* in the south. | Pacific Ocean    **Fiji Is.**  C:\Users\User\Pictures\Fiji banded iguana.PNG  *Picture of Fiji banded iguana retrieved from:* [*https://en.wikipedia.org/wiki/Fiji\_banded\_iguana*](https://en.wikipedia.org/wiki/Fiji_banded_iguana)  *Picture retrieved from:* [*www.ck12.org*](http://www.ck12.org) | | **Temporal (including seasonal – timing of activity / reproduction) isolation**  Timing of mating activity for an organism may prevent contact with closely related species: nocturnal, diurnal, spring, summer, autumn, spring tide etc. Plants flower at different times of the year or even at different times of the day. Closely related animals may have quite different breeding seasons, e.g. two species of duck may breed at different times of the year. This reduces or eliminates the chance of fertilization between the species. | *Picture retrieved from:* [*https://www.google.com/search?q=types+of+ducks*](https://www.google.com/search?q=types+of+ducks)      Breeding season for species B:  July – October  Breeding season for species A:  March - June | | **Ecological (habitat) isolation**  Ecological isolation results from differences in habitat within the same geographical area so that the populations rarely come into contact with each other. Two different herbivorous insect feed and mate on different species of plants. Closely related species may occupy different habitats even within the same general area. In the USA, geographically isolated species of antelope squirrels occupy different ranges either side of the Grand Canyon. The white tailed antelope squirrel inhabits desert to the north of the canyon (valley), while the smaller Harris’s antelope squirrel has a more limited range to the south of the canyon. | Harris’s antelope squirrel  Grand Canyon    C:\Users\User\Pictures\harris's antelope squirrel.PNG  *Picture of Grand Canyon retrieved from:* [*https://www.google.com/search?q=grand+canyon&source*](https://www.google.com/search?q=grand+canyon&source)  *Picture of Harris’s antelope squirrel retrieved from:*  *http://www.my-photo-blog.com/harris-antelope-squirrel* | | **Gamete isolation**  Gametic isolation results from incompatibility of gametes. Even if mating takes place, most gametes will fail to unite. Sperm may not be able to fertilise an egg of another species because:   * the egg’s surface does not have the correct chemical receptor(s) * sperm cannot penetrate the surface of the egg * sperm cannot survive in the chemical environment of the female reproductive system. | Amphibian ovary (*Rana*) Mammalian sperm  C:\Users\User\Pictures\human sperm.PNG  Mammalian sperm  C:\Users\User\Pictures\amphibian ovary.PNG  *Picture of frog’s ovary retrieved from: https://embryology.med.unsw.edu.au/embryology/index.php*  *Picture of human sperm retrieved from:* *https://www.cbsnews.com/pictures/sperm-15-crazy-things-you-should-know/2/* | | **Behavioural (ethological)**  Animals attract mates with calls, rituals, dances, body language, pheromones, etc. Complex displays, such as the flashes of fireflies, are quite specific. In animals, behavioural responses are a major isolating factor, preserving the integrity of mating within species. Birds exhibit a remarkable range of courtship displays that are often quite species-specific. | Peacock display of tail Blue footed boobies courtship      *Picture of peacock retrieved from:* [*https://www.csmonitor.com/Science/2016/0428/Peacock-feather-physics-How-this-train-rattling-display-might-woo-potential-mates*](https://www.csmonitor.com/Science/2016/0428/Peacock-feather-physics-How-this-train-rattling-display-might-woo-potential-mates)  *Picture of blue footed boobies retrieved from:* [*https://www.youtube.com/watch?v=t7MKVWpdQZ0*](https://www.youtube.com/watch?v=t7MKVWpdQZ0) | | **Structural (morphological)**  Shape of the copulatory (mating) apparatus, appearance, coloration, insect attractants. Insects have a lock-and-key arrangement for their copulatory organs. Pheromone chemical attractants, which may travel many kilometers with the aid of the wind, are quite specific, attracting only members of the same species. | Damselflies mating  Beetles mating      *Picture of beetles mating retrieved from:*  [*https://bugguide.net/node/view/85597*](https://bugguide.net/node/view/85597)  *Picture of damselflies mating retrieved from:*  [*https://www.google.com/search?q=Damselflies+mating&source*](https://www.google.com/search?q=Damselflies+mating&source) | |

**Lesson Activity**

**Question One**

List six **pre-mating, pre-zygotic** reproductive isolating mechanisms. (L2)(Bio4.4.2.3)

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4. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
5. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
6. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Question Two**

Describe the features of the six pre-mating isolating mechanisms listed above.

**(L2)(Bio4.4.2.4)**

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**Question Three**

Explain why geographical isolation leads to reproductive isolation. **(L3)(Bio4.4.3.1)**

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**Question Four**

Explain why ecological isolation leads to reproductive isolation. **(L3)(Bio4.4.3.2)**

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**Question Five**

Explain why behavioural isolation leads to reproductive isolation. **(L3)(Bio4.4.3.3)**

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**Question Six**

Explain why Structural isolation leads to reproductive isolation. **(L3)(Bio4.4.3.4)**

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**Question Seven**

Explain why temporal isolation leads to reproductive isolation. **(L3)(Bio4.4.3.5)**

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**Lesson 3: Post-zygotic**

**The specific learning outcomes (SLO) targeted in this activity are provided below:**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **SLO#** | **Specific Learning Outcomes:** Students are able to | **Skill level** | **SLO code** | **Achieved**  **(Yes / No)** |
| 12 | Define hybrid inviable | 1 | Bio4.4.1.3 |  |
| 12 | Define hybrid sterile | 1 | Bio4.4.1.3 |  |
| 12 | Define hybrid breakdown | 1 | Bio4.4.1.3 |  |
| 13 | Identify/State a feature or example of hybrid inviable in a given context | 1 | Bio4.4.1.4 |  |
| 13 | Identify/State a feature or example of hybrid sterile in a given context | 1 | Bio4.4.1.4 |  |
| 13 | Identify/State a feature or example of hybrid breakdown in a given context | 1 | Bio4.4.1.4 |  |
| 14 | List the post-mating (post-zygotic) reproductive isolating mechanisms | 2 | Bio4.4.2.4 |  |
| 15 | Explain why hybrid inviable mechanism leads to reproductive isolation | 3 | Bio4.4.3.6 |  |
| 16 | Explain why hybrid sterile mechanism leads to reproductive isolation | 3 | Bio4.4.3.7 |  |
| 17 | Explain why hybrid breakdown leads to reproductive isolation | 3 | Bio4.4.3.8 |  |
| 18 | Discuss the combined impact of reproductive isolating mechanisms (pre-zygotic and post-zygotic) on speciation in populations using specific examples | 4 | Bio4.4.4.1 |  |

**Notes:**

|  |
| --- |
| **Postzygotic (After Fertilisation)**   * Although the sperm and egg may fuse, there may be other problems along the path to the development of a fertile adult. The post-zygotic (post-mating) reproductive isolating mechanism are: **hybrid Inviability**, **hybrid sterility**, **hybrid breakdown** (disadvantage). * **Hybrid Inviability:** Mating between individuals of two different species may sometimes produce a zygote. In such cases, the genetic incompatibility (mismatch) between the two species may stop development of the fertilized egg at some embryonic stage. Fertilized eggs often fail to divide because of unmatched chromosome numbers from each gamete (a kind of aneuploidy between species). Very occasionally, the hybrid zygote will complete embryonic development but will not survive for long. * **Hybrid Sterility:** The offspring might reach maturity, but they might be sterile so that they cannot have offspring of their own. A common example of this is the offspring of female horses and male donkeys, mules, which are infertile. Horses have 64 chromosomes and donkeys have 62, but a mule has 63. Because this is an odd number, the chromosomes cannot pair up during meiosis and so no viable sex cells are produced.   **C:\Users\User\Pictures\horse donkey mule.PNG**  *Picture retrieved from:* [*https://www.quora.com/How-do-donkeys-look-like-the-mule*](https://www.quora.com/How-do-donkeys-look-like-the-mule)   * **Hybrid Disadvantage/Breakdown:** Even if the hybrids can have offspring they may be less fertile than normal or be less likely to survive, perhaps because they have characteristics part way between the two species, each of which is well adapted to its specific environment. The hybrid is adapted to neither. This is not to be confused with hybrid vigour, which occurs when offspring from two very inbred parents (homozygous for many genes) of the same species are stronger and healthier than the parents. |

**Lesson Activity**

**Question One**

In your own words, define the following terms: **(L1) (Bio4.4.1.3)**

i. Hybrid inviable: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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ii.hybrid sterile: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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iii.hybrid breakdown: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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**Question Two**

For the following examples, state the postzygotic feature. **(L1)(Bio4.4.1.4)**

a. A cross between a zebra stallion (2n = 44) and donkey jenny (2n = 62) results in a zebronkey offspring (2n = 53).





Zebra stallion

X

Zebra stallion Donkey jenny



Zebronkey

*Picture of zebra retrieved from:* [*http://www.rarityacres.com/zebras.php*](http://www.rarityacres.com/zebras.php)

*Picture of donkey retrieved from:* [*https://www.britannica.com/animal/donkey*](https://www.britannica.com/animal/donkey)

*Picture of zebronkey retrieved from:* [*http://fms507warwickgbravenewworld.blogspot.com/2015/11/more-hybrids-in-nature.html*](http://fms507warwickgbravenewworld.blogspot.com/2015/11/more-hybrids-in-nature.html)

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b. A cross between Species A and Species B produced fertile first generation, but the second generation were infertile or inviable.

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c. A zygote was produced when two different species mated. The hybrid zygote completed embryonic development but did not survive for long.

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d. The pollen from a hibiscus flower joins with the ovule of a sunflower. The two different chromosome sets did not divide properly preventing full development.

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**Question Three**

List the **post-mating, post-zygotic** reproductive isolating mechanisms.

**(L2)(Bio4.4.2.5)**

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**Question Four**

Explain why hybrid inviable mechanism leads to reproductive isolation. **(L3)(Bio4.4.3.6)**

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**Question Five**

Explain why hybrid sterile mechanism leads to reproductive isolation. **(L3)(Bio4.4.3.7)**

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**Question Six**

Explain why hybrid breakdown leads to reproductive isolation. **(L3)(Bio4.4.3.8)**

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**Question seven**

Discuss the combined impact of reproductive isolating mechanisms (pre-zygotic and post-zygotic) on speciation in populations using specific examples.  **(L4)(Bio4.4.4.1)**

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