Bio Factsheet

Number 92

Isolation Mechanisms

This Factsheet will explain:

- **the nature of isolation mechanisms, including both pre-zygotic and post-zygotic types;**
- **some roles and actions of isolation mechanisms in evolution and speciation.**

The overall role of isolation mechanisms

Genetic variation arises from five sources. These are:

- polygenic (multiple allele) inheritance.
- random assortment of chromosomes in meiosis I and of chromatids in meiosis II.
- chiasmata formation in meiosis I.
- fertilisation, particularly enhanced by outbreeding.
- gene mutations and chromosome mutations.

The sources of variation are covered in detail in Factsheet 50, Sources of genetic variation.

When all of the individuals of a population can interbreed, these variations will not produce new species. The variation may allow the formation of a number of different races or varieties of the species but these could still interbreed with other members of the species, even when of different races.

Remember: – *A species is a population of similar organisms all of which can interbreed to form fertile offspring. Members of a species cannot produce fertile offspring with members of another species.*

Before a new species can develop a barrier must form that restricts breeding and gene flow between populations. Such a barrier, which prevents gene exchange, is called an **isolating mechanism**.

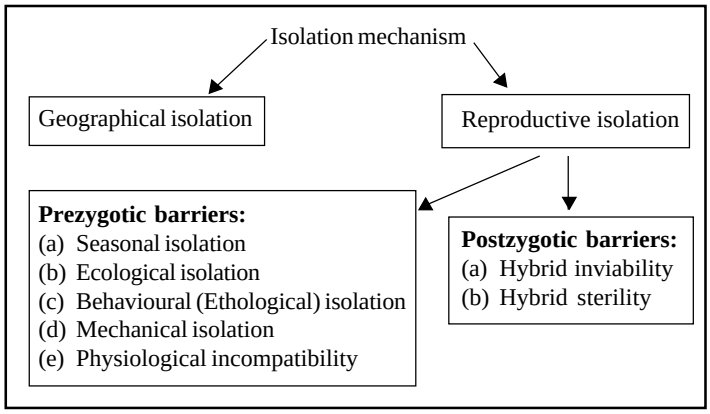
Once such a barrier is in place then the isolated populations can continue to vary independently by the usual mechanisms. They eventually may become so different from each other that they can no longer interbreed successfully - they have become separate species.

Barriers to interbreeding may be:

- **prezygotic** - these prevent fertilisation happening.
- **postzygotic** - fertilisation may occur but any offspring are either not viable or are themselves sterile.

Fig 1 shows a classification of isolation mechanisms.

Fig 1. Isolation mechanisms



Remember: *–The genetic variations that occur are acted upon by natural selection. This enables the organisms with the most favourable variations to survive and reproduce more effectively. This may enhance differences between isolated populations of a species, especially if different selective pressures operate in the different populations.*

Speciation

Isolation mechanisms can operate to cause the emergence of new species, in one of two possible ways**:**

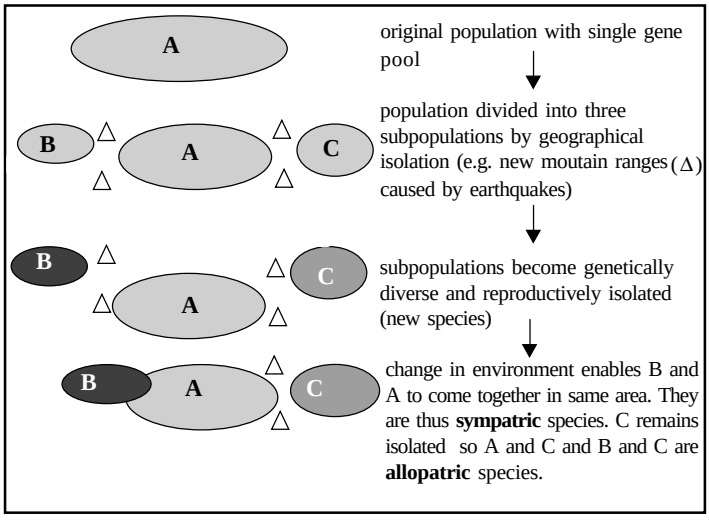
- **Allopatric speciation** occurs between geographically isolated populations. The gene pool of the speciesis physically seperated, so the seperate populations can then evolve independently of each other.
- **Sympatric speciation** occurs when organisms inhabiting the same area become seperated into two or more reproductively isolated groups.

Simple model of speciation

1. Initially an existing genetically varying population is physically divided into two or more sub-populations so that the free exchange of genes can no longer occur. This could be caused by geographical isolation, for instance, when part of a land mass becomes detached as an island, or a mountain range produced by earthquakes.
2. Once the sub-populations are spatially separated they can diverge genetically. Their environments will be different so different genetical variations will be selected.
3. Eventually the genetic divergence will be so extensive that the groups would no longer be able to interbreed, even if they were brought together again. At this stage they are reproductively isolated and can be considered to be different species.

This model of speciation is illustrated in Fig 2.

Fig 2. A model of speciation.



Exam Hint :– *Questions will often be of data interpretation type. Read the data given carefully and then apply your knowledge to give reasoned answers. If you are asked to write a continuous prose essay about 'isolation mechanisms' make sure you explain their roles and importance Do not be tempted to describe too many examples at the expense of omitting some types of isolation mechanism.*

Examples of particular isolation mechanisms

Prezygotic barriers (preventing fertilisation)

1. Geographical isolation
Geographical barriers to gene flow may be formed by mountain ranges, glaciers, canyons, seas and rivers, enabling speciation to occur.

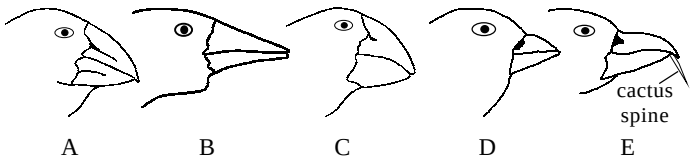
- Grand Canyon in Colorado, USA, is no barrier to flying birds but it is to rodents. The north and south rims have the same identical bird species but different species of rodents.
- The Galapagos islands lie 600 miles west of Ecuador in South America. The islands are volcanic in origin and have never been attached to the mainland. The finches inhabiting them must have arisen from a single mainland species and come across the sea, possibly carried on driftwood or blown by wind currents.

  The finches became established on several of the islands and since each island population was separated from the others by sea (finches will not fly across wide stretches of water), they were geographically isolated and thus diverged and evolved into distinct species (allopatric speciation).

2. Ecological isolation
This occurs when species inhabit the same geographical area but occupy different habitats or ecological niches within the area.

- The Wild Pansy (*Viola tricolor*) grows on acid soils whereas the Field Pansy (*Viola arvensis*) grows on calcareous soils.
- In the Galapagos islands, the finches within one population on an island diverge and become adapted enabling them to occupy different ecological niches (fig 3).

Fig 3. Beak shapes of Galapagos finches



A: fruit or bud-eating finches, with a parrot-like beak
B: insect-eating tree finches
C: cactus-eating ground finches
D: seed-eating finches
E: woodpecker-like finches which use cactus spines as tools to dislodge insects from crevices in the bark.

Because these species overlap in territory they have evolved by sympatric speciation. Altogether there are 13 different species of finch on the Galapagos Islands.

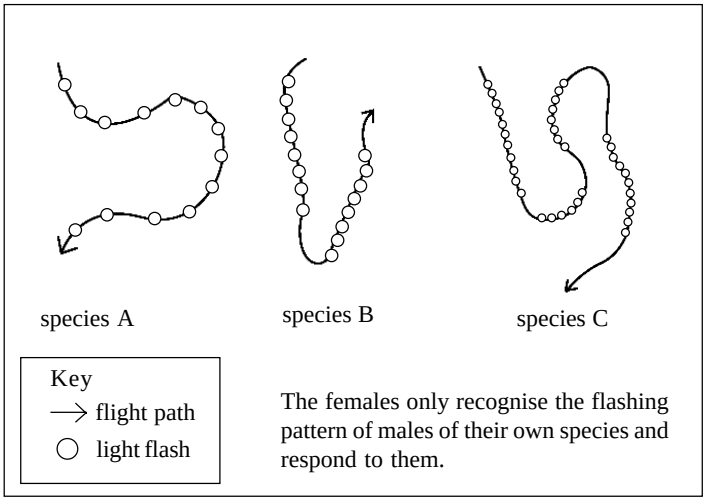
3. Seasonal isolation
This occurs when populations exist in the same area but are sexually mature at different times of the year.

- In California, *Pinus radiata* cones mature in February but *Pinus attenuata* cones mature in April. So these pine trees cannot hybridise together.
- In Britain the common marbled carpet moth (*Dysstroma truncata*) mates at different times of the year to the closely related dark marbled carpet moth (*Dysstroma citrata*).

4. Behavioural isolation
This occurs when animals exhibit species-specific courtship patterns. Mating only occurs if the courtship display by one sex results in acceptance by the other sex.

- Many species of fish, bird and insect exhibit highly specific courtship colourations, movements and dances to attract the opposite sex.
- Birds also use specific bird song to communicate between the sexes.
- Male spiders of many species approach the female for mating by 'semaphore' signals with the palps and legs – the male spider that gives the wrong signals will probably get eaten!
- Different species of firefly have different courtship flashing patterns (fig 4).

Fig 4. The flashing patterns of males of three species of fire flies



5. Mechanical isolation
This occurs in animals where differences in the shape of genitalia prevent mating between closely related species.

- The male palps of spiders, which are used to insert sperm into the epigyne (female genital opening) are extremely complex in shape and can only fit the complex epigyne of the specific female by a 'lock and key' mechanism.
- In milkweeds the pollen is released in small sacs which stick to the legs of insects. The stigmas have small slits into which the sacs must be inserted for pollination to occur. The sacs of pollen and stigma slits are of complementary shape in each species and will not fit together with different species.

6. Physiological incompatibility
This is common in grasses and clovers. The stigma produces genetically-determined proteins which inhibit or retard the germination and growth of foreign pollen, even from closely related species.

Postzygotic barriers (prevent the development/fertility of hybrids)

1. Hybrid inviability
Although hybrids are formed, they are usually weak and malformed and die before they can reproduce.

- When different species of tobacco plant hybridise, the hybrids develop tumours in their vegetative parts and die before flowering occurs.
- In North America, hybrids formed by interbreeding between the northern and southern races of the leopard frog (*Rana pipiens*) invariably die in the tadpole stage, preventing gene flow between these two races of frogs.

2. Hybrid sterility
In this case the hybrid may be vigorous and grow to adult size. It will however be sterile because meiosis will fail to produce gametes. This is because the different parent species have different chromosome shapes (and possibly different chromosome numbers). Thus pairing of homologous chromosomes (synapsis) cannot occur in meiosis.

- The sterile mule (2n = 63) results from a cross between a horse (2n = 60) and a donkey (2n = 66).
- A horse and a zebra can interbreed to form a sterile zebroid.

Tip: *– Obviously in a Factsheet of this length the number of examples quoted must be very limited. If you wish to know more examples either refer textbooks on evolution or if you have internet access, search for 'isolation mechanisms' – you will find a wealth of examples described.*

Practice Questions

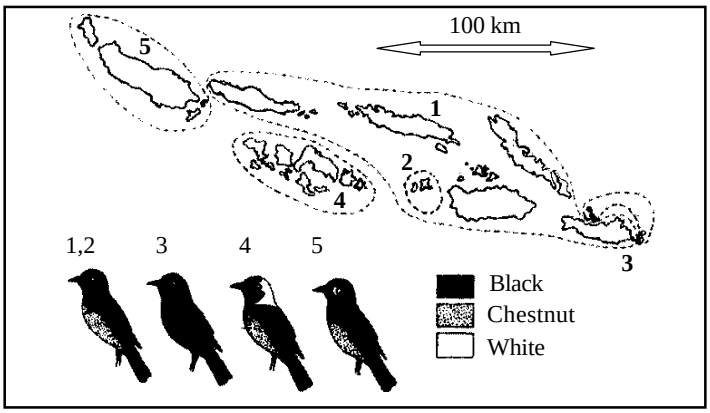
1. Read through the following passage about speciation and isolation mechanisms and then complete it by filling in the spaces with the most appropriate word or words.

Isolation mechanisms (barriers) restrict ..... flow between populations thus allowing the separated populations to diverge genetically from one another, leading to the formation of new separate species.
Speciation occurring due to an isolation mechanism operating within a gene pool, in a single geographical region, is known as ..... speciation.
Speciation due to isolation mechanisms operating on gene pools in different geographical regions is known as ..... speciation. The type of isolation mechanism which results in this type of speciation is ..... isolation.
Reproductive isolation is classed into two main types. The first type is .....isolation in which populations may be prevented from completing fertilisation and zygote formation. This type of isolation mechanism includes .....isolation, when populations live in the same locality but mature at different times of the year and .....isolation when populations live in the same area but in different habitats.
The second type of reproductive isolation is ..... isolation in which fertilisation occurs but the hybrids formed are either .....or 10

2. (a) Explain the meaning of each of the following terms;
   (i) Species 2
   (ii) Isolating mechanism 2

   (b) Distinguish between each of the following pairs;
   (i) Allopatric and sympatric speciation 4
   (ii) Prezygotic reproductive isolation and postzygotic reproductive isolation 4

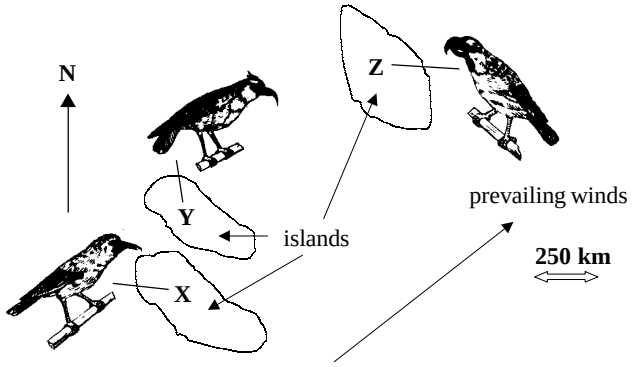
3. The diagram below shows plumage variation in four subspecies of the flycatcher, Monarcha castaneoventris of the Solomon Islands in the South Pacific Ocean, and their distribution throughout the islands. These subspecies of flycatcher can still interbreed successfully.



   (a) Suggest and explain a mechanism by which the different subspecies may have arisen. 5

   (b) What further events must occur before the subspecies become full independent species? Explain your answer. 4

4. Three distinct populations of birds, X, Y and Z live separately on three isolated oceanic islands. The birds are all omnivorous, eating insects, tiny seeds and nectar, but have slightly different beaks and feather colourings. The islands are frequently swept by strong south-westerly gales. Populations X and Y can interbreed and form fertile offspring. Population Y can interbreed with population Z but the offspring are sterile. Population X will not even mate with population Z and artificial insemination of Z birds with X bird sperm is unsuccessful.



   (a) Suggest an explanation why populations X and Y can still interbreed and form fertile offspring. 4

   (b) Suggest an explanation why mating between Y and Z produces sterile offspring. 5

   (c) Suggest an explanation for the inability of populations X and Z to mate. 5

5. Read through the following passage and then answer the questions below.

Although evolution is usually considered to be a very slow process it can sometimes occur quickly. For example, salmon were introduced into Lake Washington, (in Washington State, USA), in 1937.
line 5 Since then they have evolved into two distinct populations which are reluctant to breed with each other.
line 7 One population has become adapted to breeding in a river environment, swimming up the rivers and streams which enter Lake Washington. The other population has become adapted to
line 10 lay their eggs in the shallows near the lake's beaches.
line 11 The male river fish have developed shallower-shaped bodies that enable them to swim against strong river currents easily because shallow bodies offer less resistance to water flow. The female river fish have become much bigger than the lake fish and consequently dig much deeper nests in the river bed in which to lay their eggs. Because the eggs are deeply covered they are less likely to be
line 17 washed away or eaten.

   (a) Do you consider the two populations (line 5) to be distinct species? Explain your answer. 2

   (b) Classify the type of isolation mechanism described in this passage (lines 7 to 10). 3

   (c) Outline the process which enabled to the two forms of salmon to evolve (lines 11 to 17). 5

Answers

1. gene; sympatric; allopatric; geographical; prezygotic; seasonal; ecological; postzygotic; inviable; sterile; (these two points can be given either way round) 10

2. (a) (i) a population of similar organisms that are able to interbreed to form fertile offspring; they are reproductively isolated from other such populations/cannot interbreed with other species to form fertile offspring; 2

   (ii) an obstacle to interbreeding;
   thus limiting gene flow between parts of the gene pool;
   thus enabling divergence; max 2

   (b) (i) Allopatric: speciation due to populations occupying different geographical areas;
   thus there is no gene flow between the populations;
   Sympatric: speciation where the populations occupy the same geographical locality;
   but gene flow is restricted between the populations/demes; 4

   (ii) Prezygotic: prevents fertilisation and the formation of zygotes;
   Any two examples:
   geographical isolation/
   seasonal/mature at different times/
   ecological/live in different habitats but in same region/
   behavioural/incompatible mating rituals/incompatibility/cannot fertilise due to physiological incompatibility;;
   Postzygotic: fertilisation can occur but hybrids are either not formed or are sterile; 4

3. (a) from the distribution map it is clear that) the populations are isolated on different islands/groups of island**;**
   even though they are not separated by huge distances/may not like flying over water/psychological barrier to crossing water;
   gene mutations/genetic variation may cause different plumage patterns/colours;
   which are selected for/of survival/camouflage value on different islands;
   since interbreeding is restricted these variations can become established;
   but if they do interbreed chromosomes can still pair in meiosis so gametes can be made (by offspring)/ not reproductively isolated;
   also courtship rituals are still compatible/not behaviourally isolated; max 5

3. (b) continued restriction on interbreeding/isolation;
   continued mutation/genetic variation;
   this must be selected for and become established;
   until behavioural/mating rituals become incompatible/behavioural isolation;
   and chromosomes become so different that meiosis cannot occur in any hybrids;
   since pairing/synapsis of chromosomes cannot occur; max 4

4. (a) populations/islands X and Y are relatively close/not geographically isolated;
   thus birds can still come into contact and breed together;
   no chance for any mutations to become genetically isolated/become established;
   so little divergence occurs between X and Y/still reproductively compatible;
   population Y probably arose from population X because of prevailing winds;
   chromosomes of hybrids will still pair in meiosis (so gametes can form); max 4

   (b) populations/islands Y and Z are geographically isolated;
   thus will not normally interbreed;
   thus mutations/genetic variation in the two populations will occur independently;
   thus become isolated by postzygotic isolation/chromosomes of Y differ from those of Z/will not pair in meiosis (to form gametes);
   Z probably arose from Y as blown by winds rather than originating from X;
   not diverged sufficiently to have different courtship rituals/ behavioural patterns;
   some Y may still be blown to Z allowing occasional interbreeding (although this has now become ineffective); max 5

   (c) population/island X is geographically isolated from population Z; by ocean and island Y;
   thus mutations/genetic variation in the two populations has continued independently;
   they are now reproductively isolated because their courting/mating behaviours differ;
   incompatible mating rituals/courtship dances/plumage colours/ breeding times;
   this is prezygotic isolation;
   ref to chromosomes of X will no longer match with those of Z even if they could mate; max 5

5. (a) no; 'reluctant to breed with each other' infers that they still can interbreed (and so are still the same species/are races of the same species); 2

   (b) reproductive isolation; prezygotic isolation; ecological/behavioural isolation; 3

   (c) ref to genetic variation gave rise to different body shapes/sizes behavioural patterns;
   any three of:
   variation arising from polygenic (multiple allele) inheritance/ variation due to random assortment in meiosis /variation due to chiasmata formation in meiosis/variation arising from cross-fertilisation/variation due to gene mutations/due to chromosome mutations;;;
   ref to natural selection acting on these variations; 5

Acknowledgements:
This Factsheet was researched and written by Martin Griffin