# SPECIATION

## The Origin of New Species


### Abstract

After neglecting the subject for nearly a century after the publication of The Origin of Species evolutionary biologists have been intensively investigating the mechanisms of speciation in the last few decades. Evolutionary experiments have made an important contribution to understand the mechanism of speciation. Hence, the present work consists of literature review on speciation experiments and identify the neglected questions.



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# Speciation: The Origin of New Species

According to a new estimate described by the scientists as the most accurate ever, the natural world consists of about 8.7 million species [1]. The fact just mentioned hence proves that the living world is wildly diverse. We see a lot of different sort of organisms around us. Many of these appear to be a discrete group, separated from other groups by appearance, behaviour, ecology and genetics. But, why is the world structured like that? Why do we have these different sorts of groups and how do these come about? These are some of the questions which will be attempted to answer during this semester long project on speciation.

Figure 1: World biodiversity and speciation

Speciation is basically the origin of a new specie but before going more into the details of speciation let us first try to understand what a specie is. The definition of a specie is still a debatable topic and hence there are various different definitions of the term "specie".

According to Ernst Mayr "*Species is a group of actually or potentially interbreeding natural populations that are reproductively isolated from other such groups*". This is a fairly good definition but it does not apply to asexuals and hybrids and hence has been modified many times. In the present work, these exceptions will be neglected and the work will mostly be focused on sexually reproducing organisms.

Although all the definitions of the term specie do not incorporate reproductive isolation, whatever definition is adopted some degree of reproductive isolation is necessary for sympatric species (species with no geographical isolation) to coexist as distinguishable entities. Hence, understanding the origin of reproductive isolation is necessary for understanding the origin and maintenance of biological diversity.

**Mechanisms of Reproductive Isolation**

The mechanisms of reproduction isolation fall into three different categories. They are as follows:

- *Premating*
  It includes lack of response of females to courtship signals of males of another species.
- *Postmating but prezygotic*
  Inability of sperm to fertilize eggs of another specie.
- *Postzygotic*
  Hybrid inviability or sterility either in first generation (F1) or later generations.

An example of postzygotic isolation is shown in Figure 2.
In this example, two different yeast species, Saccharomyces cerevisiae and Saccharomyces bayonus were mated such that the first generation (F1) carried a set of nuclear and mitochondrial genomes from each of the two yeast species.
The rare F2 progeny that arose from this hybrid inherit genome segments, including the mitochondrial genome from either one of the parents are shown. So, most of the reproductive isolation occurs after F1 meiosis, which can happen but yields few viable progeny.

Out of these rare F2 viable progeny, certain combination of genes are incompatible, such as Saccharomyces bayonus gene (AEP2) on chromosome 13 is incompatible with the processing of S. cerevisiae mitochondrial gene(OLI1), resulting in loss of mitochondrial function and so inability of the F2 hybrid to undergo meiosis[7].

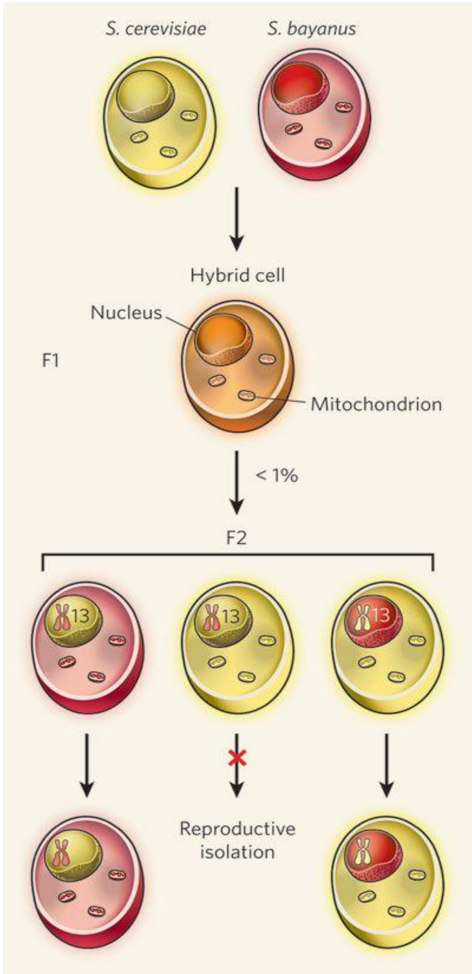
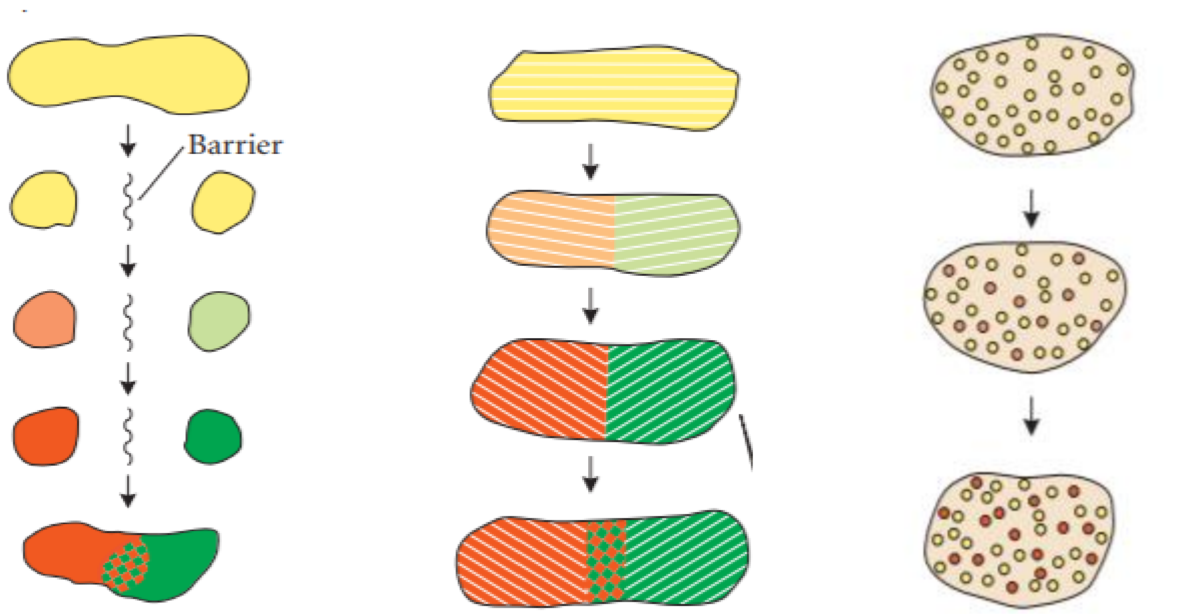



Figure 2: Hybrid sterility due to gene incompatibility

**Types of Speciation**

Reproductive barriers can also be classified on the basis of whether they arose in the presence or absence or gene flow. When the reproductive isolation evolves between geographically separated populations, it is known as *allopatric* speciation, whereas if the reproductive isolation occurs in populations with no geographical separation, it is known as *sympatric* speciation and that occurring in partially geographically isolated species is known as *parapatric* speciation.




(a) Allopatric Speciation (b) Parapatric Speciation (c) Sympatric Speciation

Figure 3: Schematic diagrams showing the successive stages in the models of speciation that differ in geographic setting [4].

Let us try to understand each of these cases separately with the help of examples.

- *Allopatric speciation*
  Consider the case of ratite birds. Ratite is a diverse group of flightless and mostly large and long-legged birds of the Southern continent. It includes the ostrich, the Cassowary, the emu, the kiwi, the elephant bird of Madagascar, the Moas of New Zealand- all of these birds originated from a common ancestor on the Gondwana and when Gondwana broke up through plate tectonics it is believed that these birds rode around on these plates to different places [2].

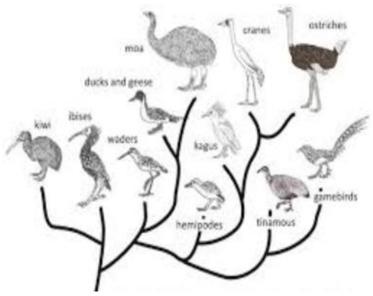
  
  

  Figure 4: Speciation in ratite birds

  Allopatric speciation is the most common mode of speciation which allows genetic divergence by natural selection and/or genetic drift. In this mode, the gene flow between the populations is reduced by geographical barriers and hence is easy to understand.

- *Parapatric speciation*
  An example of parapatric speciation would be how Galapagos flinches might have speciated on a single island. Some of them went up the mountain while others stayed on the coast resulting into parapatric speciation [3].

- *Sympatric Speciation*
  It is possible for a population where all the organisms are living in the same general place and encountering each other at the same general time to split according to ecological processes that are going on in that little area.
  Consider an orchid having cherry and apple trees. A fruit fly in the orchid switched on from living on apples to living on cherries and because the offspring were imprinted on the smell of

the fruit in which they grew up, when they grew up, they tended to go to that same kind of fruit and because mating took place on the surface of the fruit, they started to become reproductively isolated.

**The Experimental Evidences**

Over the last two decades, the study of speciation has expanded from a modest backwater of evolutionary biology to a large and vigorous discipline. In order to better understand the mechanisms of speciation, let us now try to go through some speciation experiments.

- *Destroy all the hybrids experiment*
  In this series of experiments, individuals of each sex from two different strains or incompletely reproductively isolated species were placed together and allowed to mate. It was ensured that hybrids (offsprings resulting from heterogamic matings were destroyed) and hence only homogamic mating's offsprings were allowed to contribute to the next generation. The frequency of homogamic and heterogamic matings was then monitored over successive generations. It was concluded from these experiments that **the tendency to mate assortatively can be increased by selection**.

- *Divergent selection in allopatry*
  Several experiments have been performed on allopatric speciation which show that reproductive isolation between allopatric populations often evolves due to the adaption to different environments. The geographical isolation acts as a barrier to gene flow resulting into reproductive isolation over successive generations. It was concluded from these experiments that some traits apparently show stronger pleiotropic connections to mating behaviour than others and hence when **individuals divergently selected for such traits showed significant premating reproductive isolation in mating choice tests**.

- *Disruptive selection*
  In these series of experiments, the effect of applying strong disruptive selection to a population on the evolution of premating reproductive isolation have been investigated. It was concluded from these experiments that **if a disruptively selected trait is selected so that it simultaneously serves as the basis of mate choice, it results into reproductive isolation**. If an arbitrary trait is chosen for disruptive selection it usually does not result into premating reproductive isolation.

- *Population bottlenecks*
  Population bottlenecks are the sharp reduction in the size of a population due to environmental (e.g. earthquake) or human (e.g. genocide) events as shown in Figure 4. In these series of experiments, the investigators subjected populations to bottlenecks and investigated if the population bottlenecks lead to premating isolations from each other or non-bottlenecked populations. It was concluded from these experiments that **population bottlenecks often do not lead to premating reproductive isolation**.

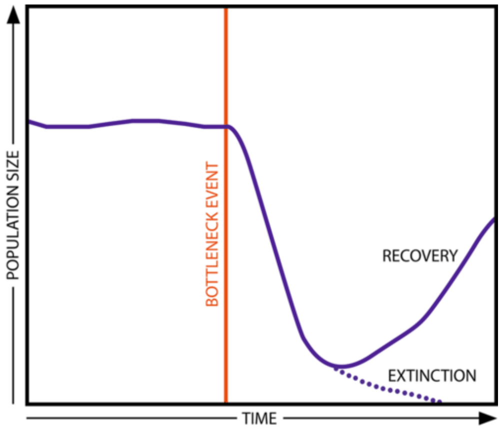



Figure 5: Population Bottlenecks

## Neglected Questions

It should be noted that the evolutionary experiments on reproductive isolation have only scratched the surface of many important questions about speciation. Hence, there are many questions about speciation that have been neglected and could be addressed by new experiments. Most of the experiments have been done on premating isolation whereas the mechanism behind postmating isolation is still unanswered. Similarly, the extent to which complete geographical isolation is a prerequisite for the initial evolution of reproductive isolation is still a mystery. Also, the mechanism behind allopatric speciation are clear where as that behind sympatric speciation are not so clear and hence still needs to be answered. Although there are evidences suggesting that host shifts have contributed to sympatric divergence in some groups or atleast maintain divergence, sympatric speciation is notoriously difficult to document in nature. Hence, in the next half of this semester long project, it would be an attempt to understand the mechanisms of sympatric speciation and identify the conditions under which it is most likely to occur.

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