# Speciation

- Darwin recognized that the young Galapagos Islands were a place for the genesis of new species.
- Evolutionary theory must also explain **macroevolution**, the origin of new taxonomic groups (new species, new genera, new families, new kingdoms)
- **Speciation** is the keystone process in the origination of diversity of higher taxa.
- The fossil record chronicles two patterns of speciation: anagenesis and cladogenesis.
- **Anagenesis** is the accumulation of changes associated with the transformation of one species into another.
- **Cladogenesis**, branching evolution, is the budding of one or more new species from a parent species.
    - Cladogenesis promotes biological diversity by increasing the number of species.

## The biological species concept emphasizes reproductive isolation

- **The biological species concept**:
    - A species is a population or group of populations whose members have the potential to interbreed with each other in nature to produce viable, fertile offspring, but who cannot produce viable, fertile offspring with members of other species.
    - A biological species is the largest set of populations in which genetic exchange is possible and is genetically isolated from other populations.
- Species are based on interfertility (the ability to successfully reproduce), not physical similarity.
- For example, the eastern and western meadowlarks may have similar shapes and coloration, but differences in song help prevent interbreeding between the two species.
- In contrast, humans have considerable diversity, but we all belong to the same species because of our capacity to interbreed.

## Prezygotic and postzygotic barriers isolate the gene pools of biological species

- Reproductive isolation prevents populations belonging to different species from interbreeding, even if their ranges overlap.

- Reproductive barriers can be categorized as prezygotic or postzygotic, depending on whether they function before or after the formation of zygotes.

- **Prezygotic barriers** obstruct mating between species or hinder fertilization of ova if members of different species attempt to mate.

  - These barriers include *habitat isolation, behavioral isolation, temporal isolation, mechanical isolation, and gametic isolation.*

- **Habitat isolation**. Two organisms that use different habitats even in the same geographic area are unlikely to encounter each other to even attempt mating.

  - This is exemplified by the two species of garter snakes, in the genus *Thamnophis,* that occur in the same areas but because one lives mainly in water and the other is primarily terrestrial, they rarely encounter each other.

- **Behavioral isolation**. Many species use elaborate behaviors unique to a species to attract mates.

  - For example, female fireflies only flash back and attract males who first signaled to them with a species-specific rhythm of light signals.

  - In many species, elaborate courtship displays identify potential mates of the correct species and synchronize maturation of the sex organs.

- **Temporal isolation**. Two species that breed during different times of day, different seasons, or different years cannot mix gametes.

  - For example, while the geographic ranges of the western spotted skunk and the eastern spotted skunk overlap, they do not interbreed because the former mates in late summer and the latter in late winter.

- **Mechanical isolation**. Closely related species may attempt to mate but fail because they are anatomically incompatible and transfer of sperm is not possible.

  - To illustrate, mechanical barriers contribute to the reproductive isolation of flowering plants that are pollinated by insects or other animals

- **Gametic isolation** occurs when gametes of two species do not form a zygote because of incompatibilities preventing fusion or other mechanisms.
    - In species with internal fertilization, the environment of the female reproductive tract may not be conducive to the survival of sperm from other species.
    - For species with external fertilization, gamete recognition may rely on the presence of specific molecules (receptors) on the egg's coat, which adhere only to specific molecules on sperm cells of the same species.
    - A similar molecular recognition mechanism enables a flower to discriminate between pollen of the same species and pollen of a different species.
- If a sperm from one species does fertilize the ovum of another, **postzygotic barriers** prevent the hybrid zygote from developing into a viable, fertile adult.
    - These barriers include *reduced hybrid viability*, *reduced hybrid fertility*, *and hybrid breakdown.*
- **Reduced hybrid viability**. Genetic incompatibility between the two species may abort the development of the hybrid at some embryonic stage or produce frail offspring.
    - This is true for the occasional hybrids between frogs in the genus *Rana*, which do not complete development and those that do are frail.
- **Reduced hybrid fertility**. Even if the hybrid offspring are vigorous, the hybrids may be infertile and the hybrid cannot backbreed with either parental species.
    - This infertility may be due to problems in meiosis because of differences in chromosome number or structure.
    - For example, while a mule, the hybrid product of mating between a horse and donkey, is a robust organism, it cannot mate (except very rarely) with either horses or donkeys.
- **Hybrid breakdown**. In some cases, first generation hybrids are viable and fertile.
    - However, when they mate with either parent species or with each other, the next generation are feeble or sterile.
- Reproductive barriers can occur<br>***before mating,***<br>***between mating and fertilization,***<br>***or after fertilization.***

# Modes of Speciation

- Two general modes of speciation are distinguished by the mechanism by which gene flow among populations is initially interrupted.
- In **allopatric speciation**, geographic separation of populations restricts gene flow – this leads to geographic isolation, and eventually to a divergence (genetically speaking) of the populations
- In **sympatric speciation**, speciation occurs in geographically overlapping populations when biological factors, such as chromosomal changes and nonrandom mating, reduce gene flow.

## Allopatric speciation: geographic barriers can lead to the origin of species:

- Several geological processes can fragment a population into two or more isolated populations.
  - Mountain ranges, glaciers, land bridges, or splintering of lakes may divide one population into isolated groups.
  - Alternatively, some individuals may colonize a new, geographically remote area and become isolated from the parent population.
    - For example, mainland organisms that colonized the Galapagos Islands were isolated from mainland populations.
- The evolution of many diversely-adapted species from a common ancestor is called an **adaptive radiation** ***(great illustration of adaptive radiation in your text; pg. 471)***.
- ***Adaptive radiation is an example of allopatric speciation.***
- In allopatric speciation, new species form when geographically isolated populations evolve reproductive barriers as a byproduct of genetic drift and natural selection to its new environment.
  - These barriers prevent interbreeding even if populations come back into contact.
  - These barriers include prezygotic barriers that reduce the likelihood of fertilization and postzygotic barriers that reduce the fitness of hybrids.

## Sympatric speciation: a new species can originate in the geographic midst of the parent species

- In sympatric speciation, new species arise within the range of the parent populations.
  - Here reproductive barriers must evolve between sympatric populations
  - In plants, sympatric speciation can result from accidents during cell division that result in extra sets of chromosomes, a mutant condition known as **polyploidy**.
  - In animals, it may result from gene-based shifts in habitat or mate preference.
  - The evolution of bread wheat is an example of sympatric speciation

## The tempo of speciation can appear steady or jumpy

- The evidence of evolution comes mainly from the fossil record.
- Two models that have proved useful in interpreting the evolutionary patterns suggested by the fossil record are the:

  gradualist model and

  punctuated equilibrium

- The ***gradualist model*** fits Darwin's view of the origin of species.
  - Populations evolve differences gradually as they become adapted to their local environments
  - New species evolve gradually from the ancestral population.
  - According to the gradualist model, big changes (speciations) occur by the steady accumulation of many small changes.
- However, few sequences of fossils have ever been found that clearly show a gradual, steady accumulation of small changes in evolutionary lineages.
- Instead, most fossils appear suddenly, without transitional forms, persist essentially unchanged, and then disappear as suddenly as they appeared
- Biologists call this non-gradual appearance of the fossil record ***punctuated equilibrium***.
- In the **punctuated equilibrium model**, the *tempo* of speciation is not constant.
  - Species undergo most morphological modifications when they first bud from their parent population.
  - After establishing themselves as separate species, they remain static for the vast majority of their existence.

# Microevolution vs. Macroevolution

- Speciation is at the boundary between microevolution and macroevolution.
  - ***Microevolution*** is a change over the generations in a population's allele frequencies, mainly by genetic drift and natural selection.
  - Speciation occurs when a population's genetic divergence from its ancestral population results in reproductive isolation.
  - While the changes after any speciation event may be subtle, the cumulative change over millions of speciation episodes must account for ***macroevolution,*** the scale of changes seen in the fossil record.

# Convergent vs. Divergent Evolution

- When one species evolves into two or more species with different characteristics, this process is called ***divergent evolution***
  - An example of divergent evolution are the 14 different species of Galapagos finches that evolved from a common ancestor
- In a process called ***convergent evolution***, species from different evolutionary branches may come to look like one another if they live in very similar environments.
  - This type of evolution produces organisms that share similarities due to <u>***analogies***</u> (similar traits – dissimilar ancestors) <u>***not homologies***</u> (similar traits - common ancestors)