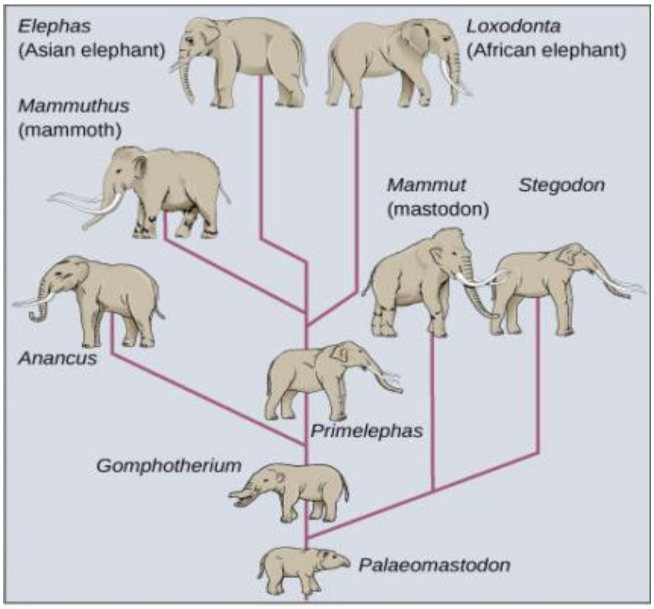
To understand speciation the concept of species needs to be clear. Ernst Mayr defined a **species** as follows: "**species** are groups of interbreeding natural populations that are reproductively isolated from other such groups”.

What is Speciation?

Speciation is the formation of new and distinct species in the course of evolution. Speciation involves the splitting of a single evolutionary lineage into two or more genetically independent lineages.

Speciation is how a new kind of plant or animal species is created. Speciation occurs when a group within a species separates from other members of its species and develops its own unique characteristics. The demands of a different environment or the characteristics of the members of the new group will differentiate the new species from their ancestors.

Discussion of most topics within Evolutionary Biology begins with Darwin. Indeed, On “The Origin of Species (1859)” continues to influence much of modern Evolutionary Biology. Darwin viewed evolution by **natural selection** as a very gradual mechanism of change within populations, and postulated that new species could be the product of this very same process, but over even longer periods of time. This eventual process of speciation by **natural selection** is illustrated by a sketch drawn by Darwin in his personal notebook nearly 20 years before the Origin of Species was published. Here, he proposed a model whereby lineages form from their ancestors by evolving different characters over relatively long periods of time. This concept can be visualised from the picture given below.



Darwin indicated that species could form by the evolution of one species splitting into two, or via a population diverging from its extant ancestor to the point it was a new species. Darwin's insights into evolution were brilliant, especially in light of their being made in the absence of genetics. Indeed, ideas about heredity and the introduction of new genetic material via mutation were to come long after Darwin's founding theories of evolution.

A major turning point for evolutionary research occurred in the 1930s when Fisher, Haldane, Wright, Dobzhansky, and others, developed mathematical population genetic models to illuminate the genetic mechanisms of evolutionary change. The integration of genetics with models of natural selection shed tremendous light on, and strengthened Darwin's views on, evolution — here was the missing mechanism that introduced new variation into populations via mutation and recombination. Indeed, thanks to the Modern Synthesis, much of current research in Evolutionary Biology is strongly tied to genetics, and current methods for studying speciation are no exception.

Under the commonly used ‘Biological Species Concept', the formation of new species involves the evolution of reproductive barriers to the production of viable offspring. Thus, new species form when individuals from diverging populations no longer recognize one another as potential mates, or opportunities for mating become limited by differences in habitat use or reproductive schedules.

Biologists think of speciation events as the splitting of one ancestral species into two descendant species.

An example of speciation is the Galápagos finch. Different species of these birds live on different islands in the Galápagos archipelago, located in the Pacific Ocean off South America. The finches are isolated from one another by the ocean. Over millions of years, each species of finch developed a unique beak that is especially adapted to the kinds of food it eats. Some finches have large, blunt beaks that can crack the hard shells of nuts and seeds. Other finches have long, thin beaks that can probe into cactus flowers without the bird being poked by the cactus spines. Still other finches have medium-size beaks that can catch and grasp insects. Because they are isolated, the birds don’t breed with one another and have therefore developed into unique species with unique characteristics. This is called **allopatric speciation**(*allo*– = “other”; –*patric* = “homeland”) **which** involves geographic separation of populations from a parent species and subsequent evolution.

Types of Speciation

There are five types of speciation: allopatric, peripatric, parapatric, and sympatric ((*sym*– = “same”; –*patric* = “homeland”)) and artificial.

Allopatric speciation occurs when a species separates into two separate groups which are isolated from one another. A physical barrier, such as a mountain range or a waterway, makes it impossible for them to breed with one another. Each species develops differently based on the demands of their unique habitat or the genetic characteristics of the group that are passed on to offspring.

When Arizona's Grand Canyon formed, squirrels and other small mammals that had once been part of a single population could no longer contact and reproduce with each other across this new geographic barrier. They could no longer interbreed. The squirrel population underwent allopatric speciation. Today, two separate squirrel species inhabit the north and south rims of the canyon. On the other hand, birds and other species that could easily cross this barrier continued to interbreed and were not divided into separate populations.

Peripatric speciation - When small groups of individuals break off from the larger group and form a new species, this is called **peripatric speciation**. As in allopatric speciation, physical barriers make it impossible for members of the groups to interbreed with one another. The main difference between allopatric speciation and peripatric speciation is that in peripatric speciation, one group is much smaller than the other. Unique characteristics of the smaller groups are passed on to future generations of the group, making those traits more common among that group and distinguishing it from the others.

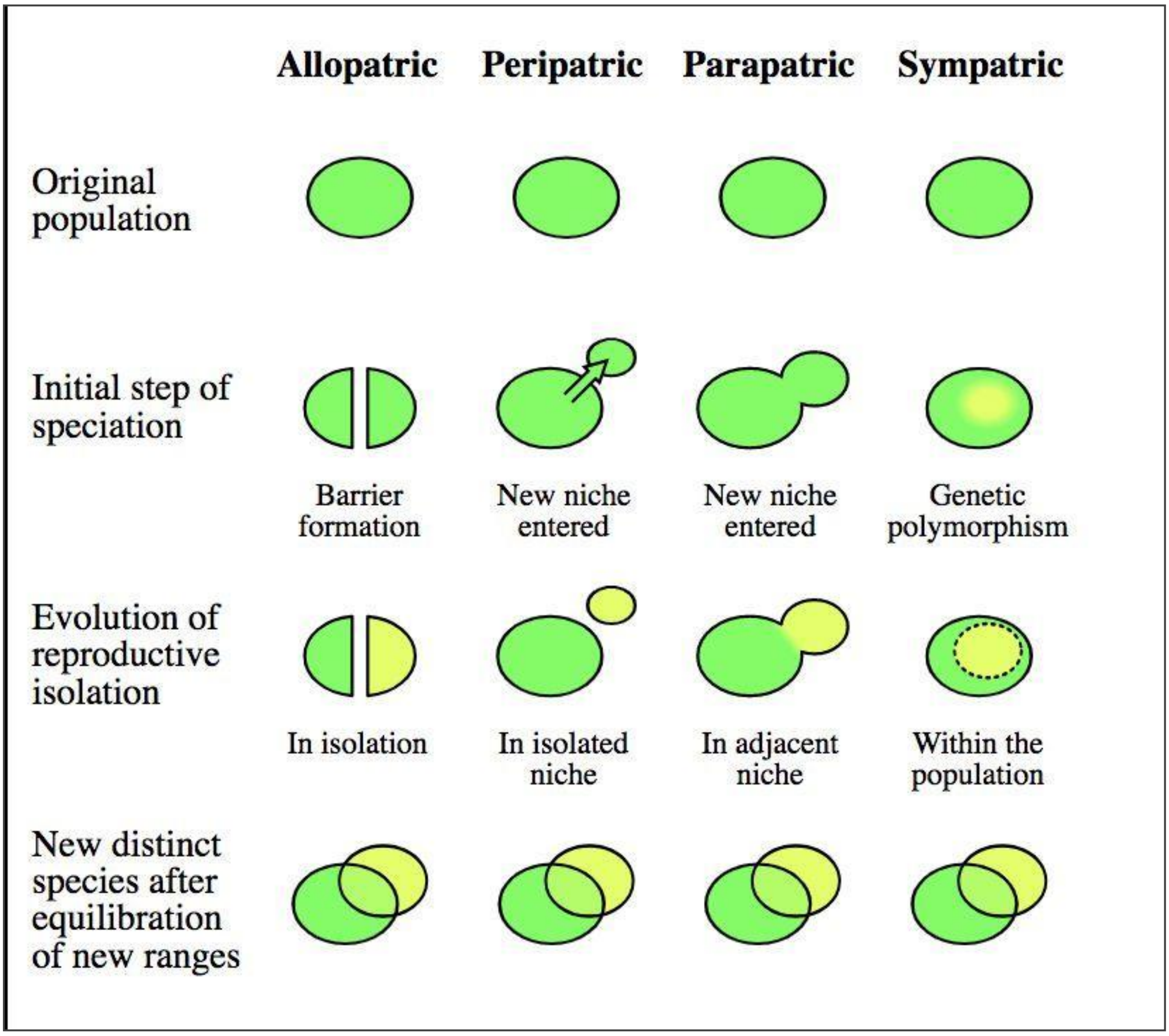
Parapatric speciation - In **parapatric speciation** a species is spread out over a large geographic area. Although it is possible for any member of the species to mate with another member, individuals only mate with those in their own geographic region. Like allopatric and peripatric speciation, different habitats influence the development of different species in parapatric speciation. Instead of being separated by a physical barrier, the species are separated by differences in the same environment. When a species is spread out over a large geographic area , although it is possible for any member of the species to mate with one another, individuals only mate with those in their own geographic region.

Parapatric speciation sometimes happens when part of an environment has been polluted. Mining activities leave waste with high amounts of metals like lead and zinc. These metals are absorbed into the soil, preventing most plants from growing. Some grasses, such as buffalo grass, can tolerate the metals. Buffalo grass, also known as vanilla grass, is native to Europe and Asia, but is now found throughout North and South America, too. Buffalo grass has become a unique species from the grasses that grow in areas not polluted by metals. Long distances can make it impractical to travel to reproduce with other members of the species. Buffalo grass seeds pass on the characteristics of the members in that region to offspring. Sometimes a species that is formed by parapatric speciation is especially suited to survive in a different kind of environment than the original species.

Sympatric speciation is controversial. Some scientists don’t believe it exists. Sympatric speciation occurs when there are no physical barriers preventing any members of a species from mating with another, and all members are in close proximity to one another. A new species, perhaps based on a different food source or characteristic, seems to develop spontaneously. The theory is that some individuals become dependent on certain aspects of an environment—such as shelter or food sources—while others do not.

A possible example of sympatric speciation is the apple maggot, an insect that lays its eggs inside the fruit of an apple, causing it to rot. As the apple falls from the tree, the maggots dig in the ground before emerging as flies several months later. The apple maggot originally laid its eggs in the fruit of a relative of the apple—a fruit called a hawthorn. After apples were introduced to North America in the 19th century, a type of maggot developed that only lays its eggs in apples. The original hawthorn species still only lays its eggs in hawthorns. The two types of maggots are not different species yet, but many scientists believe they are undergoing the process of sympatric speciation.

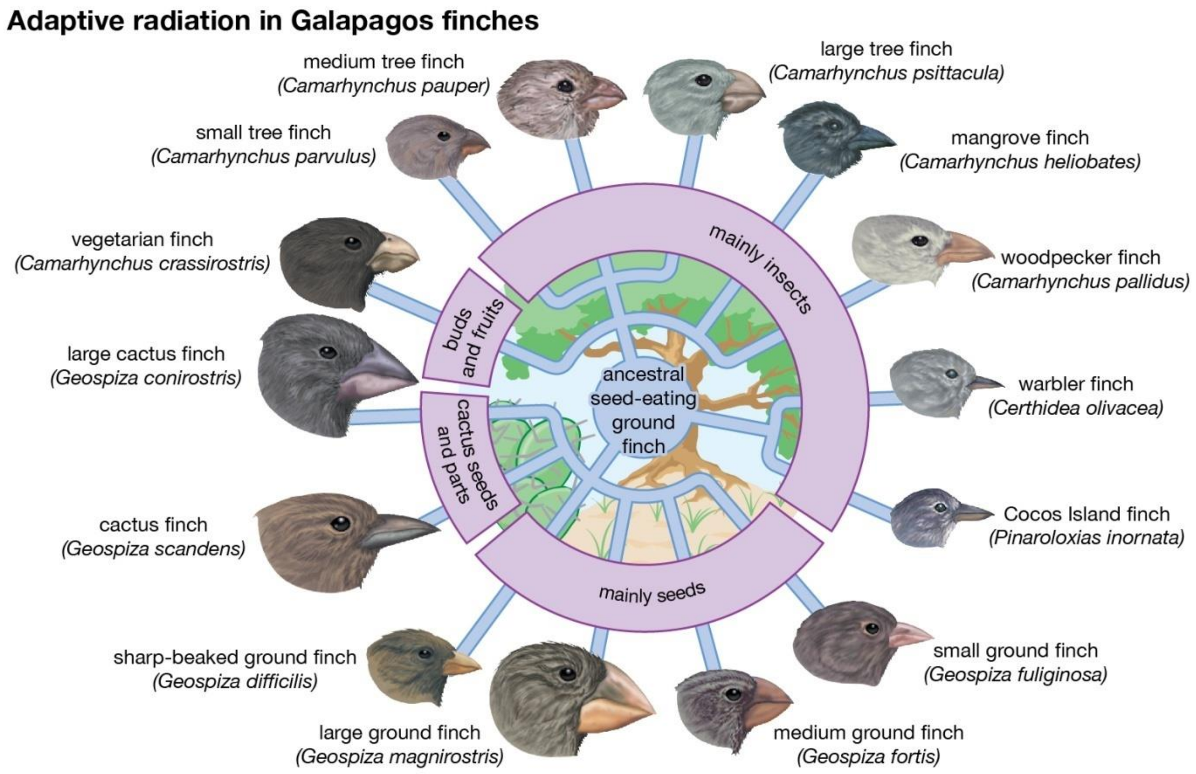
Artificial speciation is the creation of new species by people. This is achieved through lab experiments, where scientists mostly research insects like fruit flies.



Adaptive Radiation

Adaptive radiation, evolution of an animal or plant group into a wide variety of types adapted to specialized modes of life. It generally means an event in which a lineage rapidly diversifies, with the newly formed lineages evolving different adaptations.

Adaptive radiations are best exemplified in closely related groups that have evolved in a relatively short time. A striking example is the radiation, beginning in the Paleogene Period (beginning 66 million years ago), of basal mammalian stock into forms adapted to running, leaping, climbing, swimming, and flying. Other examples include Australian marsupials, cichlid fish, and Darwin's finches (also known as Galapagos finches)



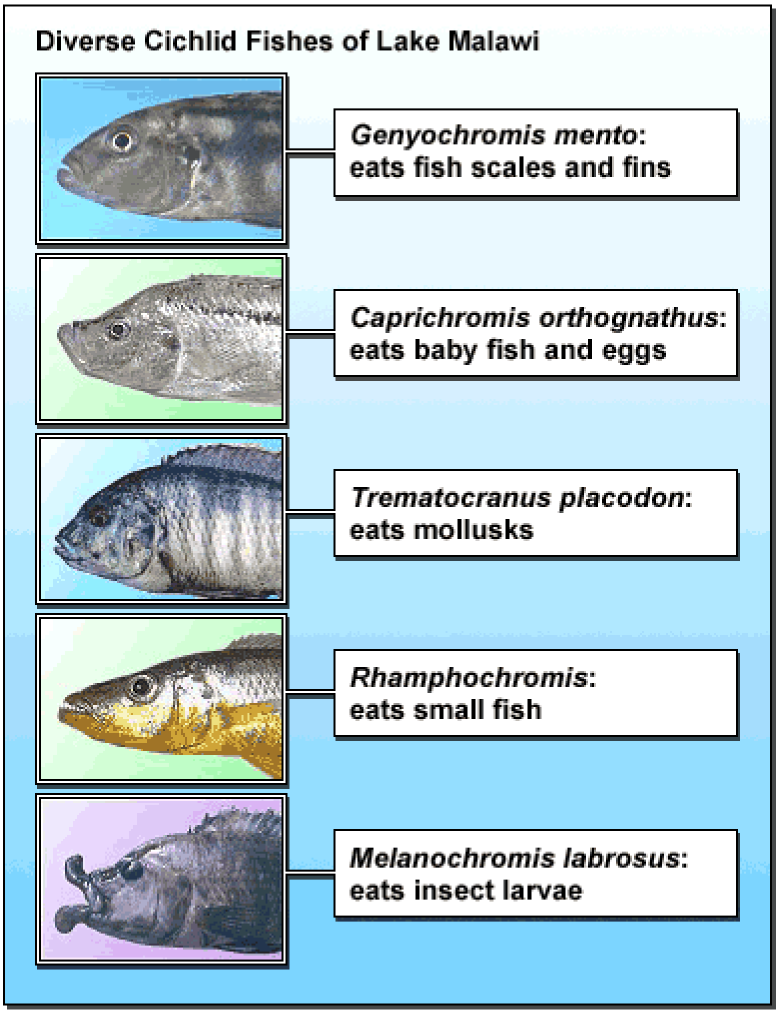
Different factors may trigger adaptive radiations, but each is a response to an opportunity. Few factors may include :-

- **The evolution of a key adaptation**
  A key adaptation usually means an adaptation that allows the organism to evolve to exploit a new niche or resource. A key adaptation may open up many new niches to an organism and provide the opportunity for an adaptive radiation. For example, beetle radiations may have been triggered by adaptations for feeding on flowering plants.

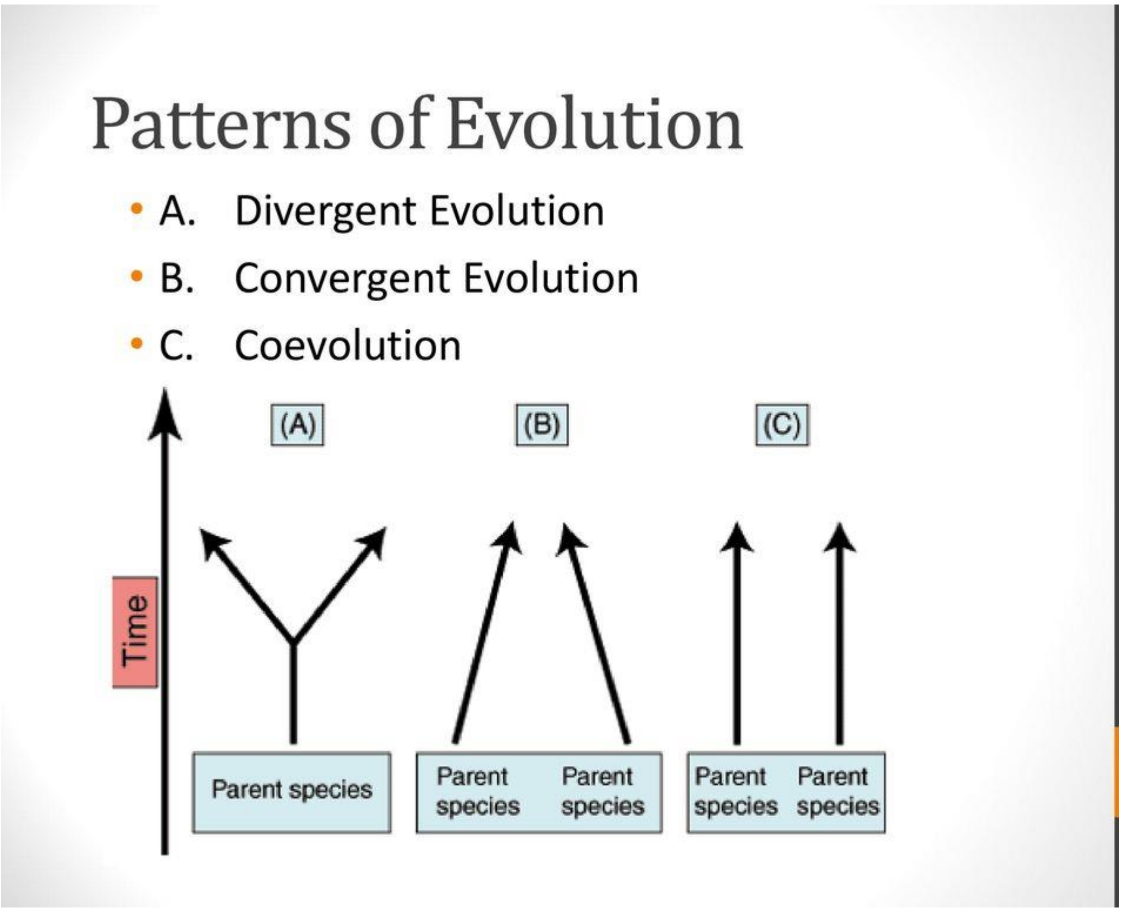
- **Release from competition/vacated niches**
  Lineages that invade islands may give rise to adaptive radiations because the invaders are free from competition with other species. On the mainland, other species may fill all the possible ecological niches, making it impossible for a lineage to split into new forms and diversify. On an island, however, these niches may be empty. Extinctions can also empty ecological niches and make an adaptive radiation possible. For example, open niches vacated by dinosaur extinctions may have allowed mammals to radiate into these positions in the terrestrial food web.

- **Specialization**
  Specialization may subdivide a single niche into many new niches. For example, cichlid fishes have diversified in East African lakes into more than 600 species. This diversification may have been possible because different fish lineages evolved to take

advantage of different foods (including insects, algae, mollusks, small fish, large fish, other fishes' scales, and even other fishes' eyes!).

- 

Convergent and Parallel evolution



Convergent evolution

In evolutionary biology, convergent evolution is the process whereby organisms **not closely related**, independently evolve **similar traits** as a result of having to adapt to similar environments or ecological niches.

It is the opposite of divergent evolution, where related species evolve different traits. On a molecular level, this can happen due to random mutation unrelated to adaptive changes.

In cultural evolution, convergent evolution is the development of similar cultural adaptations to similar environmental conditions by different peoples with different ancestral cultures.

An example of convergent evolution is the similar nature of the flight/wings of insects, birds, pterosaurs, and bats. All four serve the same function and are similar in structure, but each evolved independently.

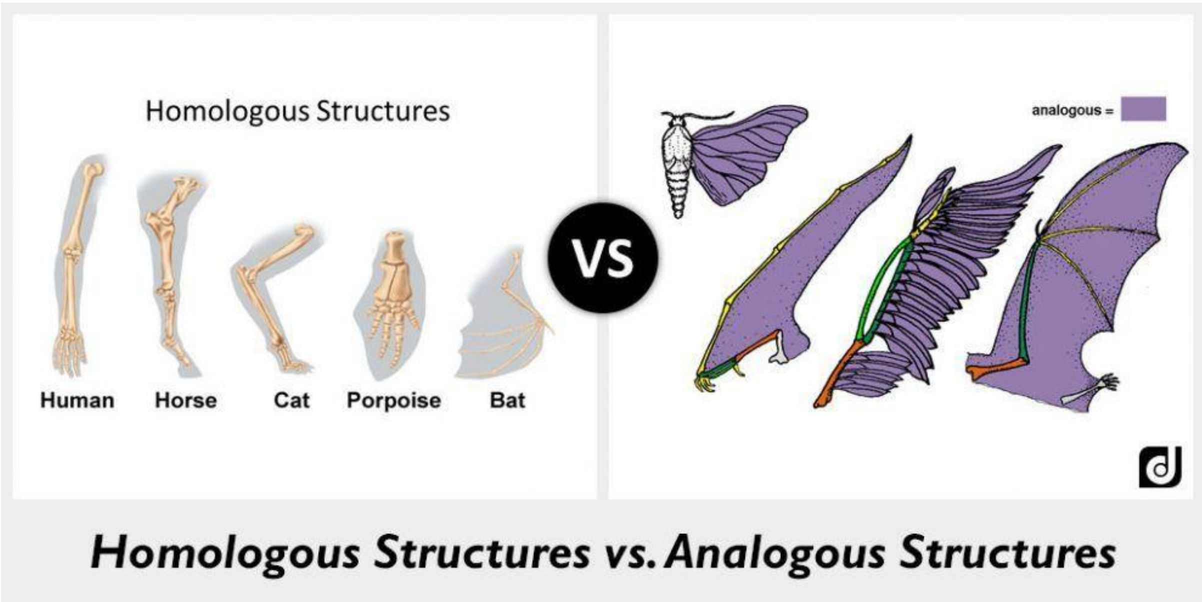
Structures that are the result of convergent evolution are called **analogous structures.**

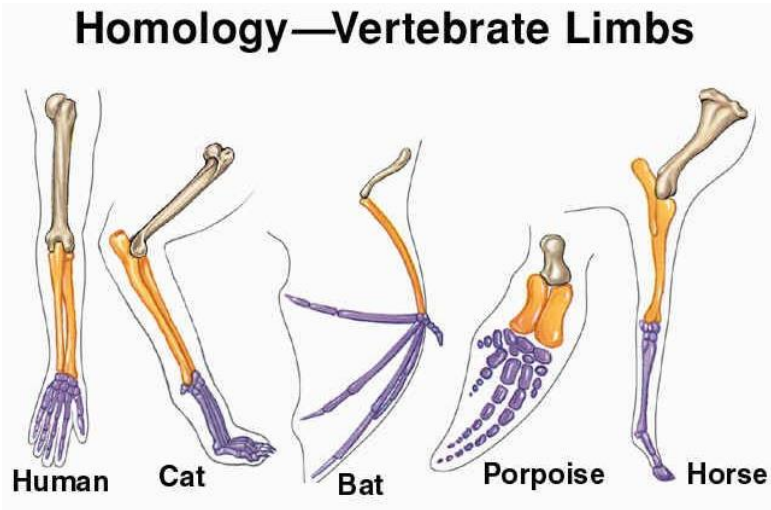
Thus features that become more similar through independent evolution are said to be convergent. Convergence is often associated with similarity of function, as in the evolution of wings in birds, bats, and flies. The shark (a fish) and the dolphin (a mammal) are much alike in external morphology; their similarities are due to convergence, since they have evolved independently as adaptations to aquatic life.

What are Analogous and Homologous structures?

Correspondence of features in different organisms that is due to inheritance from a **common ancestor** is called **homology**. The forelimbs of humans, whales, dogs, and bats are homologous. The skeletons of these limbs are all constructed of bones arranged according to the same pattern because they derive from a common ancestor with similarly arranged forelimbs.

Correspondence of features due to **similarity of function** but **not related to common descent** is termed **analogy**. The wings of birds and of flies are analogous. Their wings are not modified versions of a structure present in a common ancestor but rather have developed independently as adaptations to a common function, flying.





HOMOLOGOUS STRUCTURES
VERSUS
ANALOGOUS STRUCTURES

Homologous Structures	Analogous Structures
Homologous structures are the structures developed from a common ancestor	Analogous structures are structures of different species with similar functions
Similar in anatomy	Dissimilar in anatomy
Dissimilar in function	Similar in function
Developed in related species	Developed in unrelated species
Developed from a common ancestor	Not developed from a common ancestor
Share a similar developmental pattern	Developmental patterns are dissimilar to each other
Developed as an adaptation to different environments	Developed as an adaptation to a similar environment
Developed by divergent evolution	Developed by convergent evolution
Can be used to infer evolutionary relationships among species	Cannot be used to infer evolutionary relationships among species

Evoluttionary Relay

Convergent evolution is similar to, but distinguishable from, the phenomena of evolutionary relay and parallel evolution.

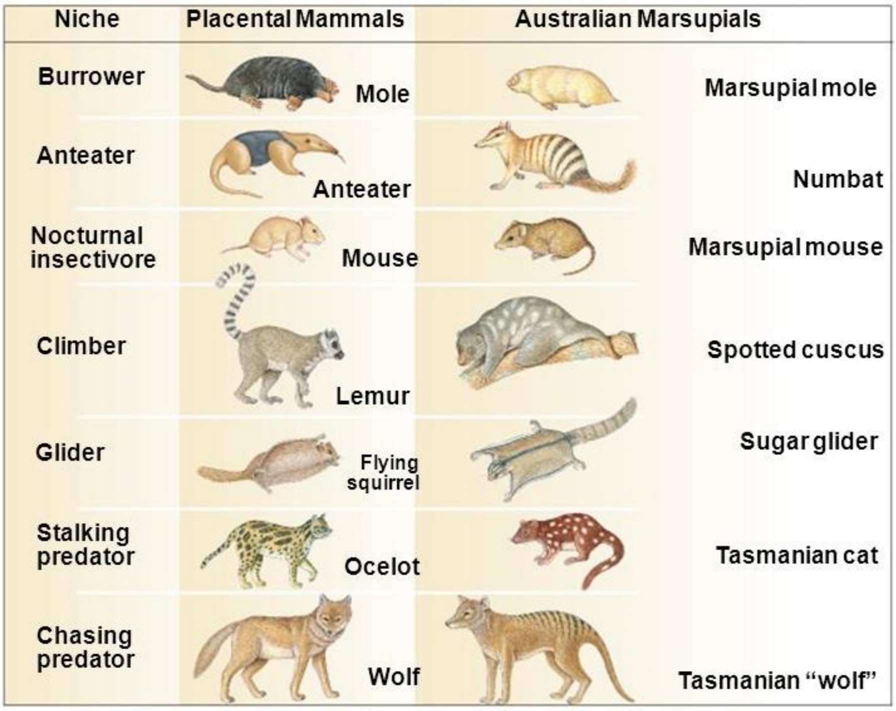
Evolutionary relay refers to independent species acquiring similar characteristics through their evolution in similar ecosystems, **but not at the same time** (e.g. dorsal fins of extinct ichthyosaurs and sharks).

Parallel Evolution

Parallel evolution is the **independent evolution** of **similar traits**, starting from a similar **ancestral condition**. Frequently this is the situation in more closely related lineages, where several species respond to similar challenges in a similar way

Parallelism and convergence are not always clearly distinguishable. Strictly speaking, convergent evolution occurs when descendants resemble each other more than their ancestors did with respect to some feature. Parallel evolution implies that two or more lineages have **changed in similar ways**, so that the evolved descendants are as similar to each other as their ancestors were.

The evolution of marsupials in Australia, for example, paralleled the evolution of placental mammals in other parts of the world. There are Australian marsupials resembling true wolves, cats, mice, squirrels, moles, groundhogs, and anteaters. These placental mammals and the corresponding Australian marsupials evolved independently but in parallel lines by reason of their adaptation to similar ways of life.



PARALLEL EVOLUTION

VERSUS

CONVERGENT EVOLUTION

PARALLEL EVOLUTION	CONVERGENT EVOLUTION
Parallel evolution refers to the independent evolution of similar traits in different but equivalent habitats	Convergent evolution refers to the independent evolution of analogous structures in unrelated species
Occurs in different but equivalent habitats	Occurs within a particular habitat
Two distinct species evolve independently, maintaining the same level of similarity	Two distinct species evolve analogous traits
Occurs in unrelated or distantly-related species	Occurs in unrelated species
Ex: Evolution of old world monkeys and new world monkeys	Ex: Development of the eye of vertebrates, cephalopods, and cnidarian