**Darwin's Theory of Evolution by Natural Selection**

Darwin's theory was based on four observations:

* Individuals within a species differ from each other - there is variation.
* Offspring resemble their parents - characteristics are inherited.
* Far more offspring are generally produced than  survive to maturity - they suffer from predation, disease and competition.
* Populations are usually fairly constant is size.

Darwin concluded that individuals that were better adapted to their environment compete better than the others, survive longer and reproduce more, so passing on more of their successful characteristics to the next generation. Darwin used the memorable phrases *survival of the fittest*, *struggle for existence* and *natural selection*.

Darwin explained the giraffe's long neck as follows. In a population of horse-like animals there would be random genetic variation in neck length. In an environment where there were trees and bushes, the longer-necked animals were better adapted and so competed well compared to their shorter-necked relatives. These animals lived longer, through more breeding seasons, and so had more offspring. So in the next generation there were more long-neck genes than short-neck genes in the population. If this continued over very many generations, then in time the average neck length would increase. [Today it is thought more likely that the selection was for long legs to run away from predators faster, and if you have long legs you need a long neck to be able to drink. But the process of selection is just the same.]

Darwin wasn't the first to suggest evolution of species, but he was the first to suggest a plausible mechanism for the evolution - natural selection, and to provide a wealth of evidence for it.

Darwin used the analogy of selective breeding (or artificial selection) to explain natural selection. In selective breeding, desirable characteristics are chosen by humans, and only those individuals with the best characteristics are used for breeding. In this way species can be changed over a long period of time. All domesticated species of animal and plant have been selectively bred like this, often for thousands of years, so that most of the animals and plants we are most familiar with are not really natural and are nothing like their wild relatives (if any exist). The analogy between artificial and natural selection is a very good one, but there is one important different - Humans have a goal in mind, nature does not.

**Types of Natural Selection****- selection and change in allele frequency**

There are three kinds of Natural Selection.

**1.**      **Directional Selection**

This occurs whenever the environment changes in a particular way. There is therefore selective pressure for species to change in response to the environmental change e.g.

* The peppered moth (studied by Kettlewell). These light coloured moths are well camouflaged from bird predators against the pale bark of birch trees, while rare mutant dark moths are easily picked off. During the industrial revolution in the 19th century, birch woods near industrial centres became black with pollution. In this changed environment the black moths had a selective advantage and became the most common colour, while the pale moths were easily predated and became rare.
* Bacterial resistance to antibiotics. Antibiotics kill bacteria, but occasionally a chance mutant appears that is resistant to that antibiotic. In an environment where the antibiotic is often present, this mutant has an enormous selective advantage since all the normal (*wild type*) bacteria are killed leaving the mutant cell free to reproduce and colonise the whole environment without any competition. Some farmers routinely feed antibiotics to their animals to prevent infection, but this is a perfect environment for resistant bacteria to thrive. The best solution is to stop using the antibiotic so that the resistant strain has no selective advantage, and may die out.
* Pesticide resistance  e.g. Warfarin (poison used to kill rats.  When warfarin was introduced, some populations already contained rates with a chance mutation that gave them resistance to the poison.  Without warfarin, stabilising selection favours normal rats – resistant rats are selected against, because they need a lot of vitamin K in their diet.  Warfarin was a new environmental factor that killed normal rats.  A few resistant rats survived, reproduced and passed on the resistance gene.  They produced a new population of resistant rats.

Populations do not have to decide to adapt, or mutate, after an environmental change.  The mutation, or combination of alleles giving resistance, have to already be there by chance, otherwise the population may become extinct.

"Environment" includes biotic as well as abiotic, so organisms evolve in response to each other. e.g. if predators run faster there is selective pressure for prey to run faster, or if one tree species grows taller, there is selective pressure for other to grow tall. Most environments do change (e.g. due to migration of new species, or natural catastrophes, or climate change, or to sea level change, or continental drift, etc.), so directional selection is common.

**2.**      **Stabilising (or Normalising) Selection.**

This occurs when the environment doesn't change. Natural selection doesn't have to cause change, and if an environment doesn't change there is no pressure for a well-adapted species to change. Fossils suggest that many species remain unchanged for long periods of geological time. One of the most stable environments on Earth is the deep ocean e.g.

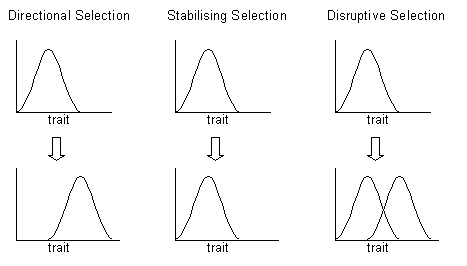
* The Coelocanth. This fish species was known only from ancient fossils and was assumed to have been extinct for 70 million years until a living specimen was found in a trawler net off South Africa in 1938. So this species has not changed in all that time.

Anther example of stabilising can be seen in the birth weight of humans.  The heaviest and lightest babies have the highest mortality and are less likely to survive to reproduce and pass on their alleles.

**3.**      **Disruptive (or Diverging) Selection.**

This occurs where an environment change may produce selection pressures that favour two extremes of a characteristic e.g.

* Grass plants in Welsh Copper mines. Soil contaminated by copper from the mines is lethal to normal grass plants, but a chance mutation allowed one plant to grow. This plant prospered and reproduced, but only on the contaminated soil. On normal soil it grew more slowly than the normal plants and was easily out-competed. So now there are two varieties growing close together.
* Sickle-cell anaemia.  People homozygous for this recessive allele usually die before reproducing.  Their red blood cells contain abnormal haemoglobin which makes them become sickle-shaped and stick in their capillaries.  People heterozygous for the allele should be at a disadvantage, because their red cells can sickle during exercise – the allele should therefore be selected against and rare, however, its frequency is high in parts of the world where malaria is common – in some populations over 20% carry the allele (as heterozygotes).  People heterozygous for sickle-cell anaemia are more resistant to malaria than people homozygous for the normal allele.  Where malaria is found, people heterozygous for sickle-cell have an advantage and are likely to survive, reproduce and pass on the allele.  People without the allele also have an advantage, because their red cells behave normally.  This produces populations with an equilibrium for numbers of people heterozygous for sickle-cell and non-carriers (balances polymorphism)



**Speciation**

A species is defined as a group of interbreeding populations that are reproductively isolated from other groups. Reproductively isolated can mean that sexual reproduction between different species is impossible for physical, ecological, behavioural, temporal or developmental reasons. For example horses and donkeys can apparently interbreed, but the offspring (mule) doesn't develop properly and is infertile. This definition does not apply to asexually reproducing species, and in some cases it is difficult distinguish between a strain and a species.

New species usually develop due to:

* geographical isolation (allopatric speciation)
* reproductive isolation (sympatric speciation)

**Geographical Isolation (Allopatric Speciation)**  

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| 1.       Start with an interbreeding population of one species. | http://www.biologymad.com/Evolution/Evolut37.gif |
| 2.       The population becomes divided by a physical barrier such as water, mountains, desert, or just a large distance. This can happen when some of the population migrates or is dispersed, or when the geography changes catastrophically (e.g. earthquakes, volcanoes, floods) or gradually (erosion, continental drift). | http://www.biologymad.com/Evolution/Evolut38.gif |
| 3.       If the two environments (abiotic or biotic) are different (and they almost certainly will be), then the two populations will experience different selection pressures and will evolve separately. Even if the environments are similar, the populations may change by random genetic drift, especially if the population is small. | http://www.biologymad.com/Evolution/Evolut39.gif |
| 4.       Even if the barrier is removed and the two populations meet again, they are now so different that they can no longer interbreed. They are therefore reproductively isolated and are two distinct species. They may both be different from the original species, if it still exists elsewhere. | http://www.biologymad.com/Evolution/Evolut40.gif |

It is meaningless to say that one species is absolutely better than another species, only that it is better adapted to that particular environment. A species may be well-adapted to its environment, but if the environment changes, then the species must adapt or die. In either case the original species will become extinct. Since all environments change eventually, it is the fate of all species to become extinct (including our own).

**Reproductive Isolation (Sympatric Speciation)**

Reproductive Isolation is a type of genetic isolation.  Here the formation of a new species can take place in the same geographical area, e.g. mutations may result in reproductive incompatibility.  A new gene producing, say, a hormone, may lead an animal to be rejected from the mainstream group, but breeding may be possible within its own groups of variants.  When this mechanism results in the production of a new species it is known as sympatric speciation.