5.1 Evidence for Evolution SL

1. What is evolution?

Can be defined as the change in heritable characteristics of a population over time. It also can be defined as a change in the frequency of alleles present in a population over time.

New species arise by evolution from pre- existing ones, and the whole of life can be seen as unified by its common origins.

2. What is the difference between heritable and acquired characteristics?

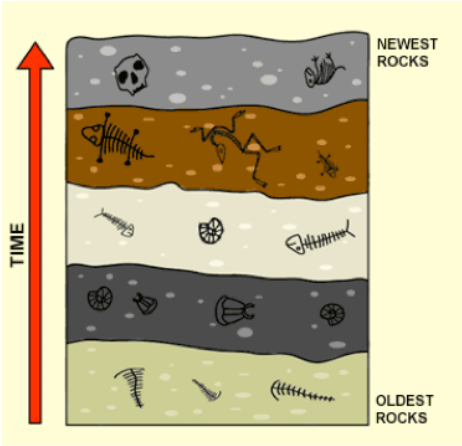
Acquired characteristics develop during the lifetime of an individual and are not inherited so are not subject to evolution. **Heritable characteristics** are passed from parent to offspring.

3. What is phylogeny?

Phylogeny means evolutionary relationships and is often shown as a family tree diagram.

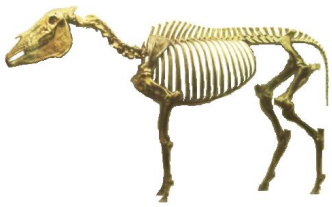
4. What are fossils and how can they indicate time?

They can be casts, imprints; whole organisms trapped in ice or resin, or petrified organisms. Layers of rock trap fossils in a time sequence. This allows scientists to sequence changes. They rock layers can also be radioisotope tested for age.



5. How do fossils provide evidence for evolution?

1. Fossils give evidence that species once lived that were not identical to modern species but definitely had similarities with existing organisms. This suggested that organisms changed over time.



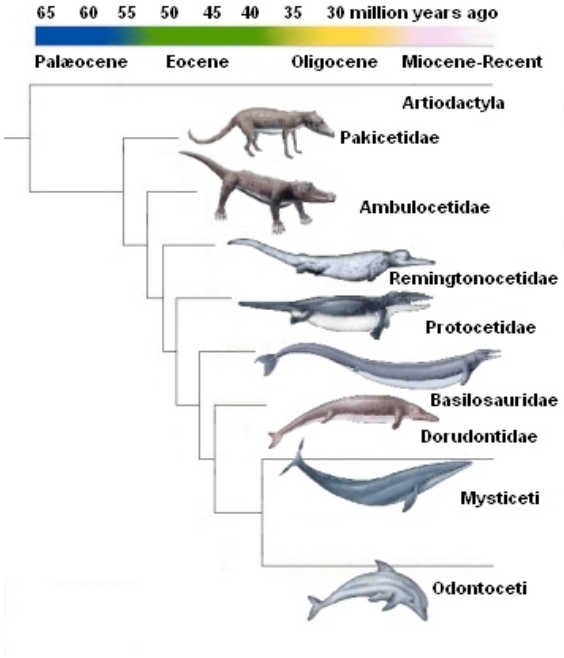
2. Fossils provide evidence that change has occurred in plants and animals and that the sequence in which fossils appear matches the expected sequence. E.g. bony fish then amphibians then reptiles then birds then mammals.

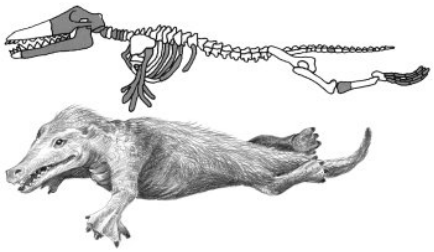
3. Fossils provide evidence of evolution by showing transitions between different forms.

Several bird-like dinosaurs fossils have been found suggesting a transition between the two.

A group of four-footed mammals that flourished worldwide for 40 million years and then died out in the ice ages is the missing link (transition) between the whale and its not-so-obvious nearest relative, the hippopotamus.

Whales and hippos had a common water-loving ancestor 50 to 60 million years ago that evolved and split into two groups



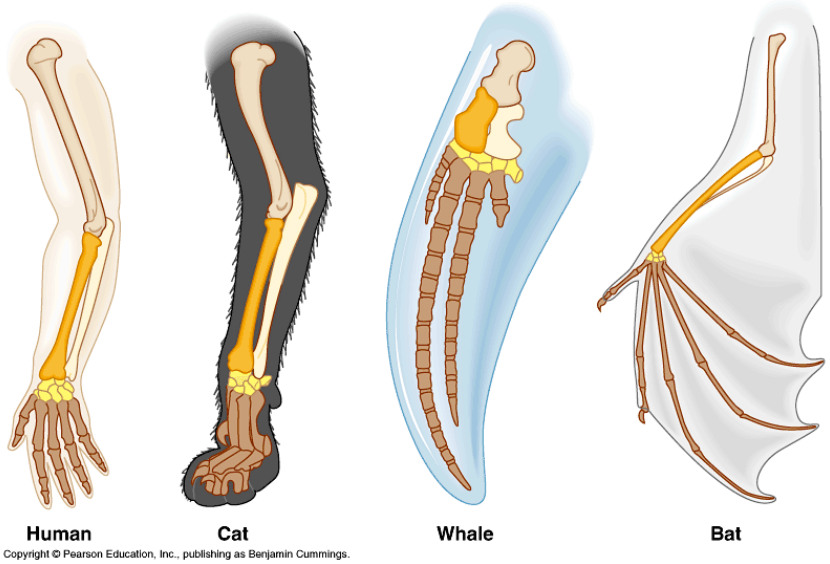


Such sequences of fossils linking existing organisms with their most likely ancestors is good evidence for evolution.

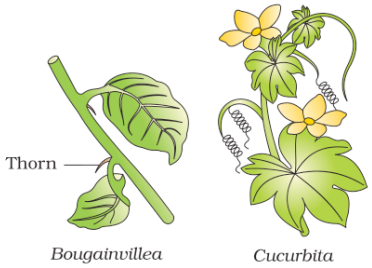
6. How do homologous structures provide evidence for evolution?

When the anatomy of species (including fossils) is compared many similarities can be found, suggesting they have evolved from a common ancestor. Such similar structures are called **homologous** structures. Superficially, they may appear different as they have evolved to do a different job.

The vertebrate pentadactyl limb is a good example – the same structure has become specialised to perform different functions according to the niche of the animal. e.g. Flying, crawling, running and swimming.



Small changes from a common limb could easily have produced these modern limbs. There are many other examples of similar structures, e.g. thorns and tendrils.

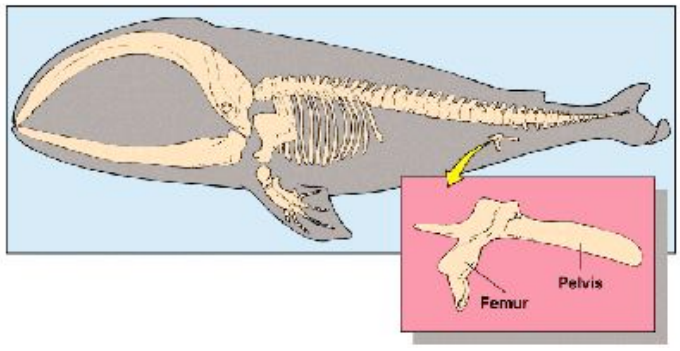


7. What are analogous structures?

Some species have superficial similarities in structure. These are called **analogous structures** and they develop when species adapt to similar conditions – e.g. streamlined body shape and fins in fish and dolphins.

8. What are vestigial or rudimentary organs?

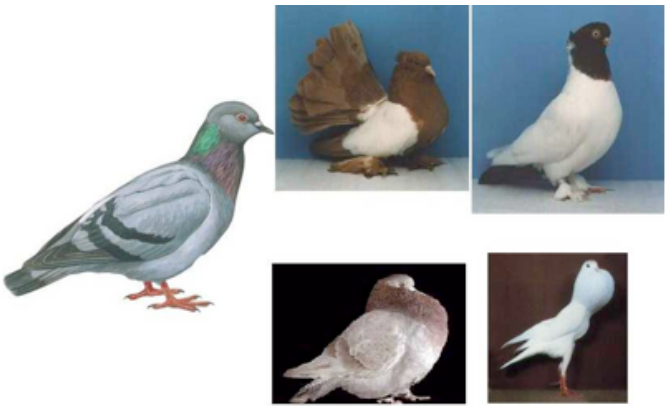
Many species show traces/remnants of organs that they inherited from an ancestor that is no longer needed. These vestigial organs show a common ancestry.



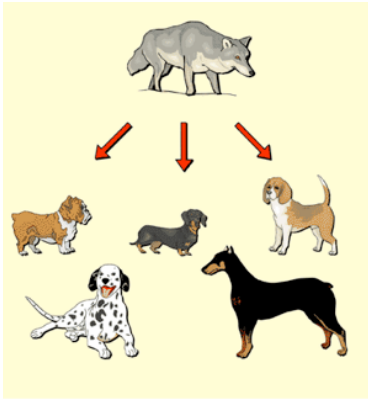
9. How does the selective breeding of domesticated animals provide evidence for evolution?

Humans have been artificially selecting for desirable traits in animals and plants since they first domesticated them. These species have changed (evolved) significantly over that time.

The breeding of pigeons is a good example.



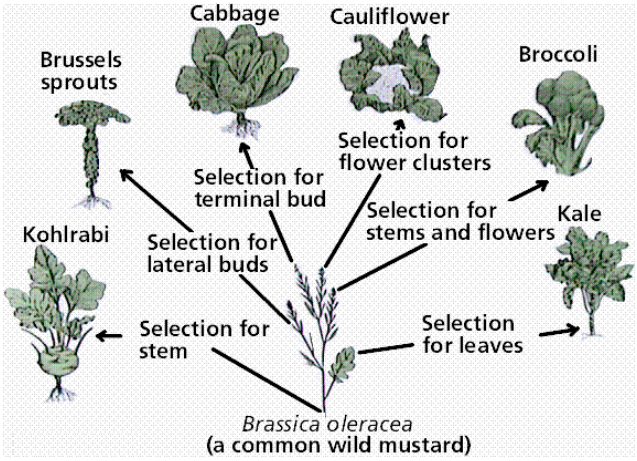
One problem facing evolution is that it is difficult to test scientifically, as one would normally do by experimentation – manipulating a variable to see the outcome. Generally, most evidence comes from observation, which makes it difficult to establish a causal link. However, selective breeding is direct evidence of the link between selection and evolutionary change.



As selected wild individuals with desirable characteristics were bred, over time this resulted in a more desirable species from a human point of view. This suggests that not only have these animals evolved but also that they can evolve rapidly.

All modern dogs have evolved from the wolf, due to selective breeding by humans, in a few hundred years.

The Brassica family of vegetables was all bred by humans from a wild form.



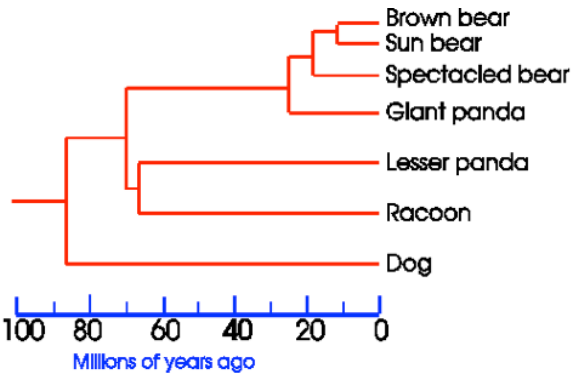
10. How does molecular evidence support evolution?

The discovery of DNA technologies such as DNA fingerprinting and sequencing have enabled scientists to compare the genetic makeup of different species. This has lead to improved understanding and evidence for common ancestry.

All organisms share the same genetic code as expected if they have evolved from a common ancestor.

When other chemicals (like haemoglobin or cytochrome) that are common to animals are compared they show how closely related the species are.

It is possible to estimate when they last had a common ancestor by the rate of mutation of the chemical (or DNA). This allows the construction of **cladograms** to demonstrate evolutionary relationships.



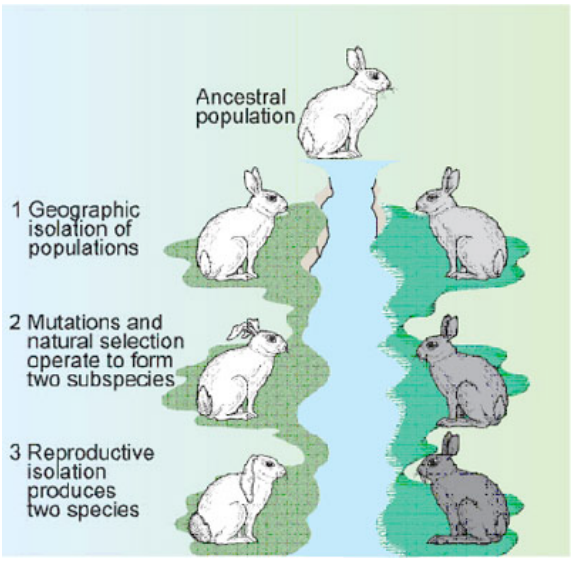
11. What is speciation?

12. How does speciation happen?

Speciation occurs when populations diverge into separate species.

If two populations become separated (e.g. by a geographical barrier) there is no **gene flow** between them – i.e. they do not interbreed.

Overtime they will become different as they get different mutations and selection in each place might be different.



Eventually they diverge so much that they can no longer interbreed if they come together. There is now a reproductive barrier. A new species has formed.

13. What does endemic mean?

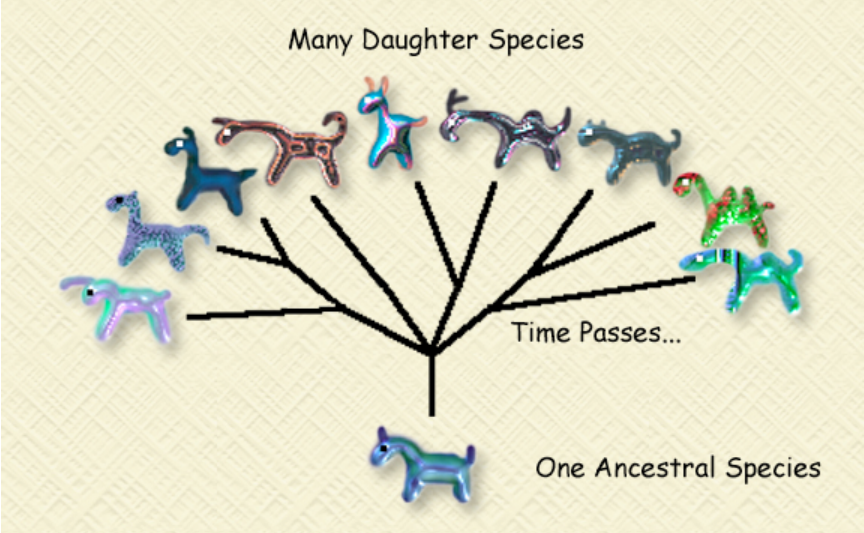
Endemic means a species is only found in that area.

14. Why are there so many endemic species on oceanic islands?

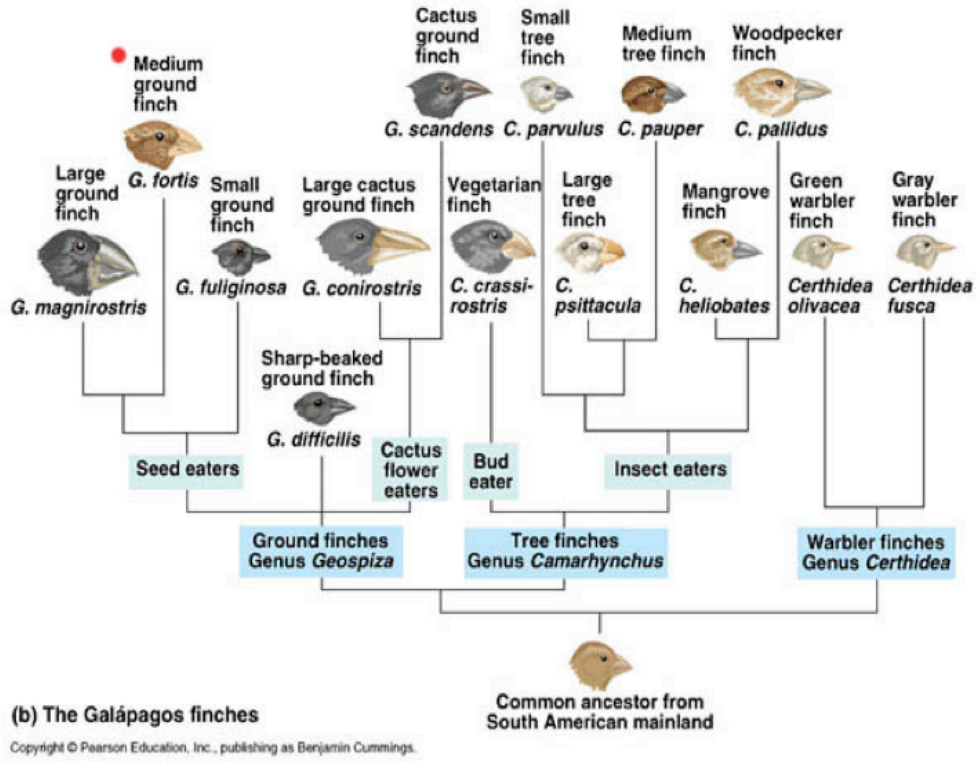
Islands make great geographical barriers to gene flow so species are isolated and speciation produces unique species.

15. What is adaptive radiation?

After an extinction event, or after a species moves to a new area (like an island) there can be rapid evolution with many new forms appearing. Each is adapted to a unique niche in the new conditions. This is called **adaptive radiation**.



16. How do the Galapagos Islands show adaptive radiation?



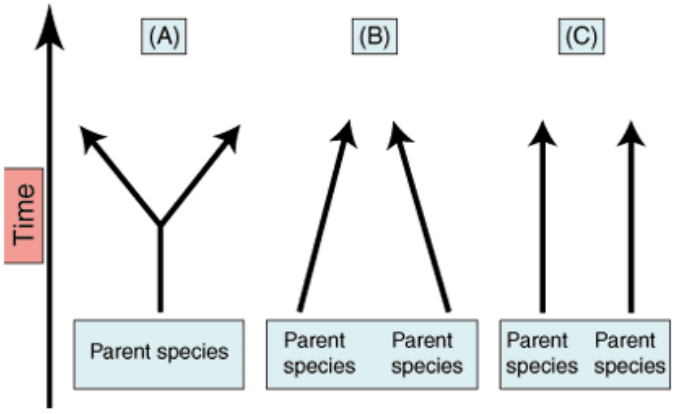
The galapagos finches are birds that evolved in isolation on oceanic islands. An ancestral finch landed on the islands to find many niches available, so over time populations diverged into many different forms.

They have developed slightly different beaks that allow them to exploit different niches. The selection was for different food sources, each requiring a different size and shape beak.

17. What are the patterns of evolution?

Evolution can be **divergent** if populations become more different over time by accumulating small differences.

It can make populations more similar by adapting to similar niches and is called **convergent** evolution.



18. How does variation across geographical ranges support evolution?

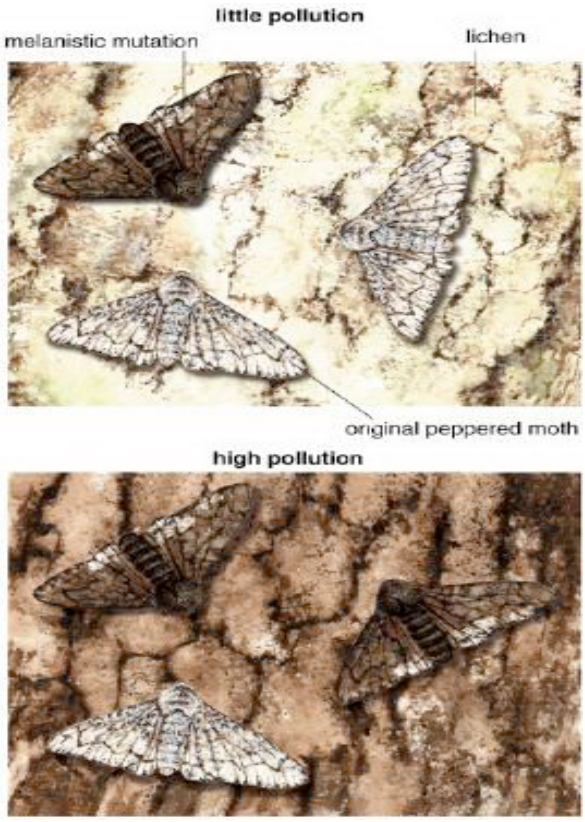
If species diverge gradually then we should see continuous variation across a geographical range. This is because we should find all stages of divergence at any one time. This is what is found in nature so it supports evolution.

19. What are melanistic insects?

Dark varieties if typically light coloured insects are called **melanistic**.

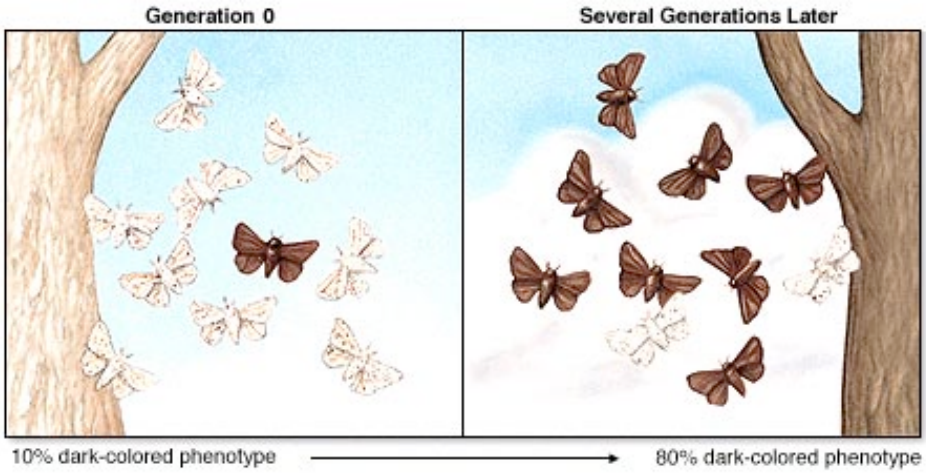
20. How is industrial melanism in moths an example of evolution in response to environmental change?

Populations of peppered moth (*Biston betularia*) in England have evolved to adapt to their environment since the industrial revolution. They rest on branches of trees during the day but must avoid predation.

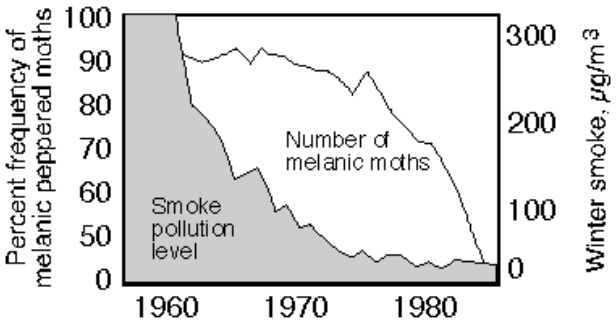


The burning of carbon greatly darkened trees around industrial areas. This gave darker moths an advantage because they were more camouflaged from predators and indeed they became more common in such areas. In areas where pollution was low the light coloured peppered moth was common.

Natural selection had favoured the moth with the best camouflage.



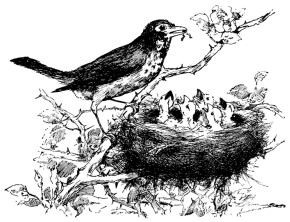
Since the 1950s controls have reduced soot emissions so there has been a reversal of the trend. Less dark moths are being found in industrial areas.



5.2 Natural Selection SL

1. Why is there a struggle for survival in populations?

All populations produce more offspring than are capable of being supported by their environment. This leads to competition among offspring for resources that are limited in supply. So not every organism will obtain enough resources to allow them to survive and reproduce.



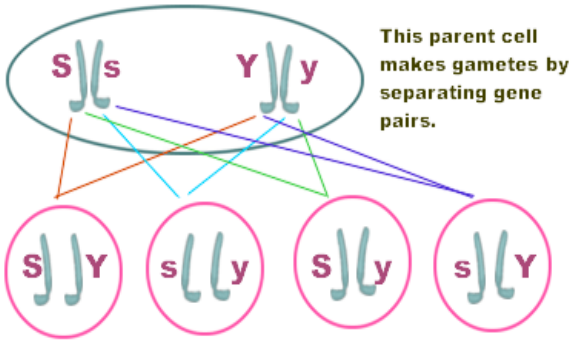
2. What is the ultimate (original) source of variation in species?

Mutations can produce new alleles and they are ultimately the source of all variation. However, they will not change a population significantly over a short period of time. E.g. DDT resistance.

3. Why do members of a species show variation?

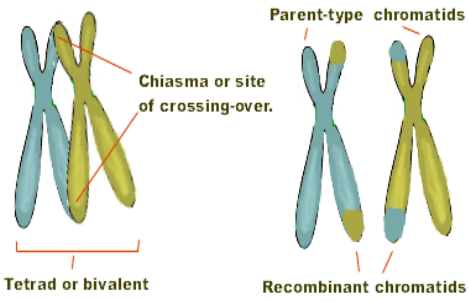
New alleles are produced by mutation but the way they come together in a plant or animal is determined by sexual reproduction. So sex produces variety by randomly sorting out existing alleles – i.e. producing new combinations of alleles. There are three processes responsible for generating the huge amount of variety found in species:

1. Independent assortment of homologous chromosomes during meiosis

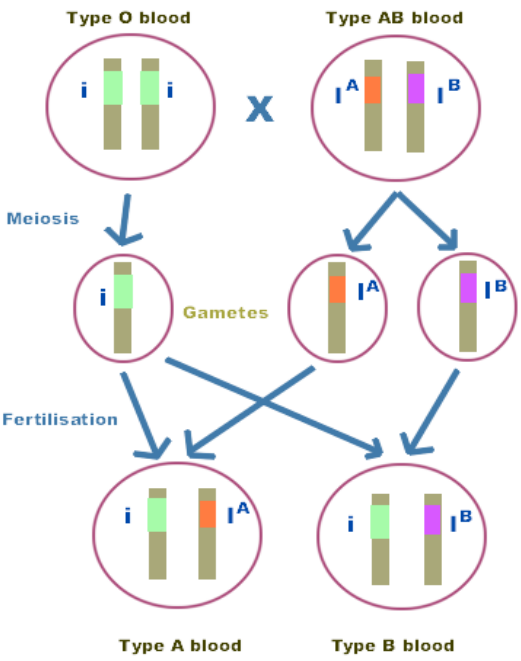


These 4 different kinds of gamete are produced in equal numbers. Notice there is only one copy of each gene in each sex cell. Every gamete must have a copy of the colour gene and a copy of the shape gene.

2. Crossing-over in meiosis



3. Random fertilisation of an egg by a sperm

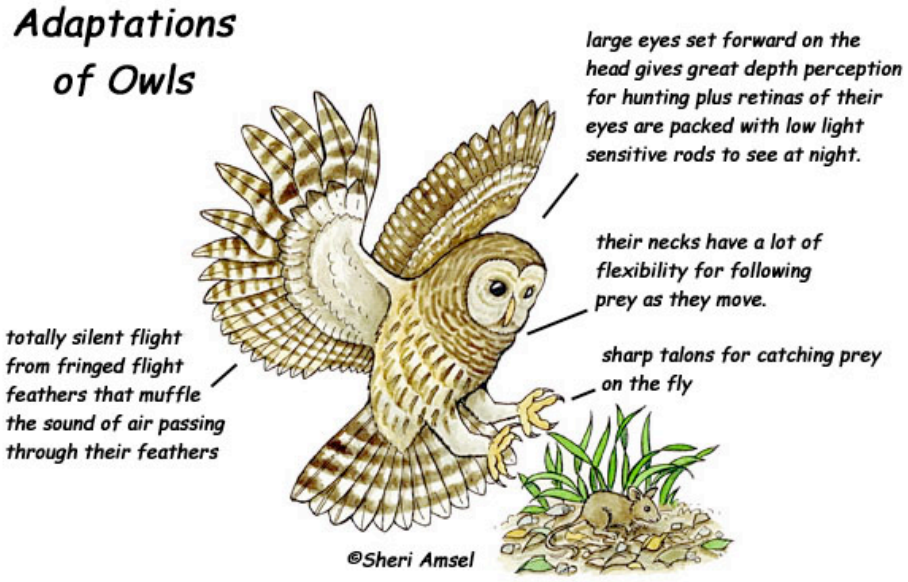


4. What does the term gene pool mean?

Members of a species show variation. We call the total alleles present in a population, the **gene pool**.

5. What is an adaptation?

An **adaptation** is a characteristic that makes an individual suited to its environment and way of life (niche). They develop over time and are inherited, so are the result of evolution.

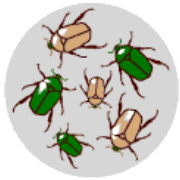


6. What is natural selection and how does it lead to evolution?

Natural selection can also be called 'survival of the fittest' and it describes the increased reproduction of advantaged individuals (better adapted) in any population. The advantaged 'type' becomes more common and this leads to a change in the gene pool, i.e. evolution.

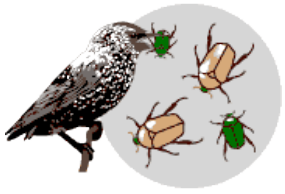
7. How does natural selection work?

1. There is variation in traits.
For example, some beetles are green and some are brown.

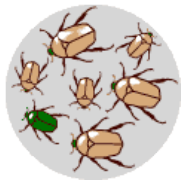


2. There is over reproduction.

More beetles are produced than can survive so they compete.



3. Some variation has an advantage because it is better suited to its environment.
In this example, green beetles tend to get eaten by birds so brown beetles survive to reproduce more.



4. Better adapted survivors pass their traits on.
The surviving brown beetles have brown baby beetles because this trait has a genetic basis (heritable).

5. End result:
The successful trait, brown colour, which allows the beetle to have more offspring, becomes more common in the population. Eventually, all individuals in the population may be brown.

8. What is selective pressure?

It describes the force causing the change in evolution. In the beetle example it was the ability to avoid being eaten by pedators.

9. How does natural selection affect populations?

Natural selection causes differential survival and reproduction of individuals but it cannot cause individuals to evolve – it just determines whether they pass on their genes. Populations change by natural selection to become better suited (adapted) to their environment.

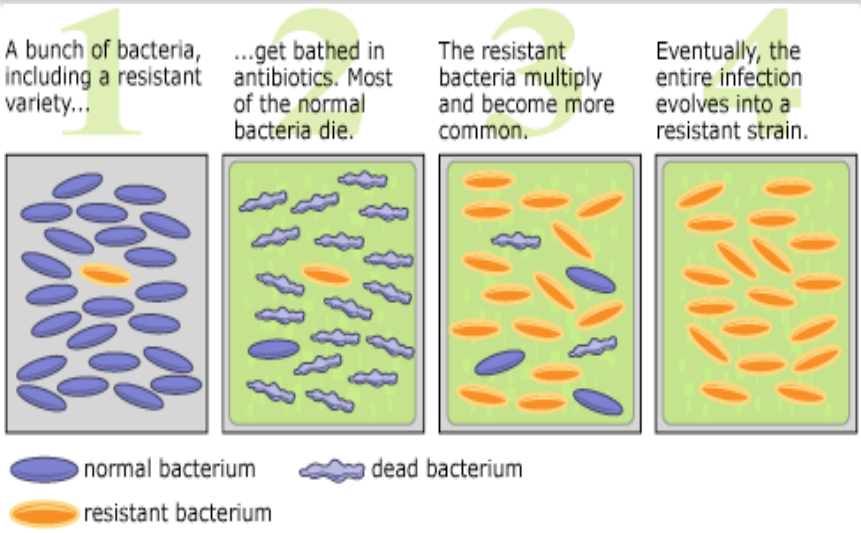
Natural selection tends to decrease variation in the population and it can only act upon genetic variation that already exists. It is important to remember that natural selection acts on the whole organism, not just bits of it. Natural selection leads to **adaptation**.

10. Why are species with little variation at risk?

The degree of adaptation that can occur is limited by the genetic variation in the population. Some populations have very little genetic variation (e.g. Cheetah) and they are at risk of extinction.

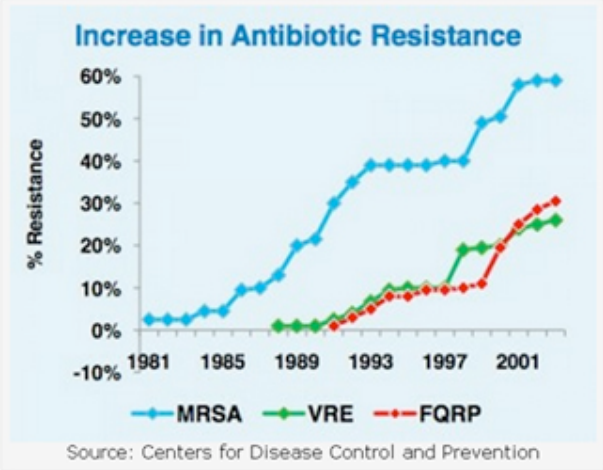
11. How is the development of antibiotic resistance in bacteria an example of evolution in response to environmental change?

Antibiotic resistance in bacteria is a common problem. In this case the environmental change is the use of antibiotic which kills bacteria. This is a very strong selective force as it kills the bacteria. If used too frequently, or improperly there may be time for a mutation to occur which gives resistance to a bacterium. This gene can spread easily as plasmids are exchanged between bacteria.



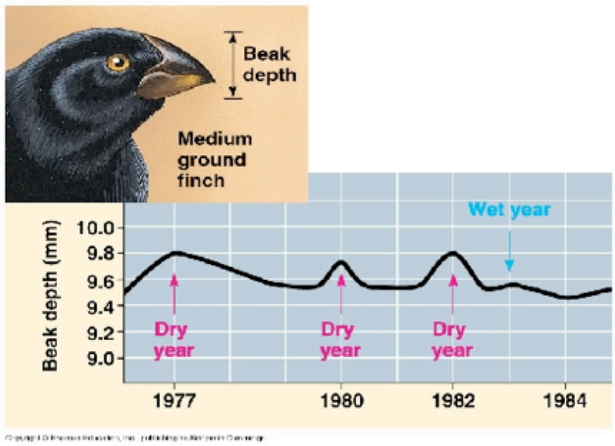
Some bacteria will then have this gene and become resistant to the specific antibiotic while others will lack the gene and so will die if exposed to the antibiotic. Over time, the non-resistant ones will all die off as doctors treat patients, but the resistant ones will survive. Eventually, the resistant ones will be the only ones left as a result of natural selection and so a new antibiotic must be created.

Bacteria reproduce rapidly and their populations can be very large so this increases the chances of mutations occurring.

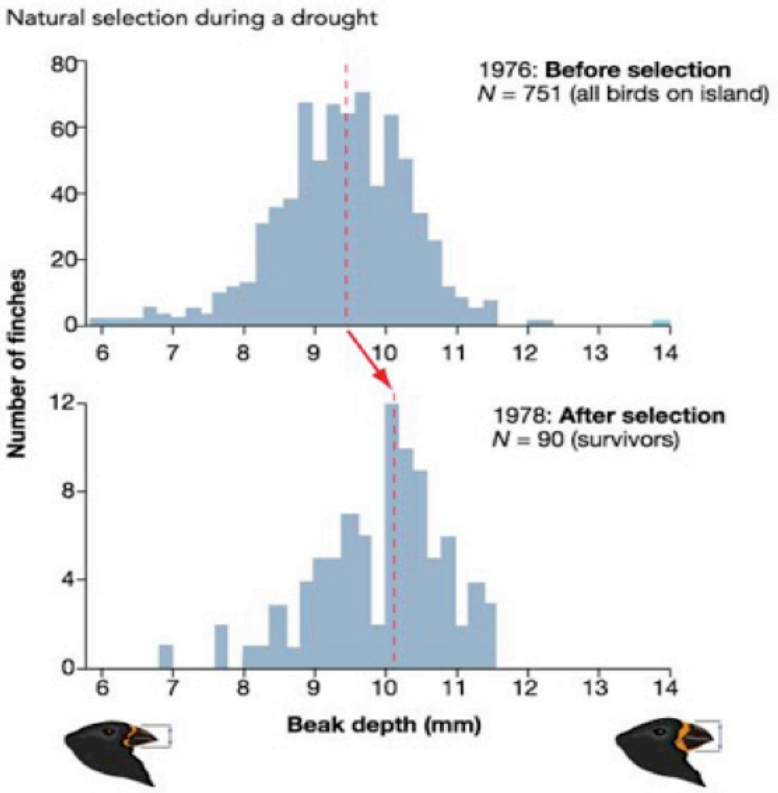


12. How are the changes in size and shape of the beaks of Galapagos finches an example of evolution in response to environmental change?

A study of 2 finch species showed that beak size changed in response to weather conditions – droughts caused beak size to increase.



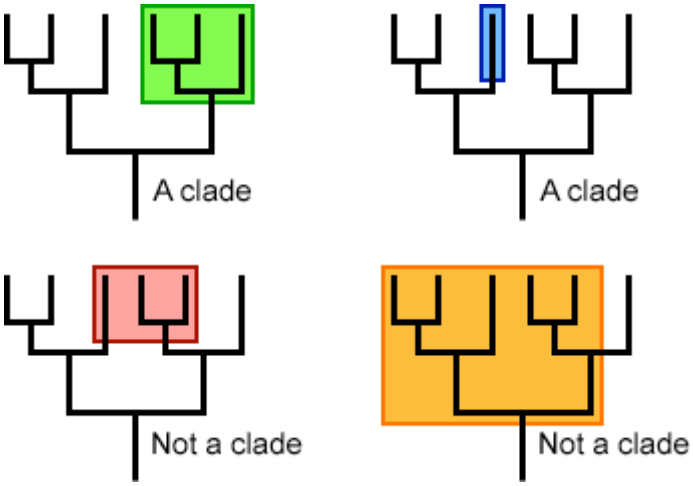
Seeds are scarce in droughts so small, soft ones get eaten quickly, leaving hard, tough ones that these finches normally don't touch. This showed natural selection changes populations quite quickly.



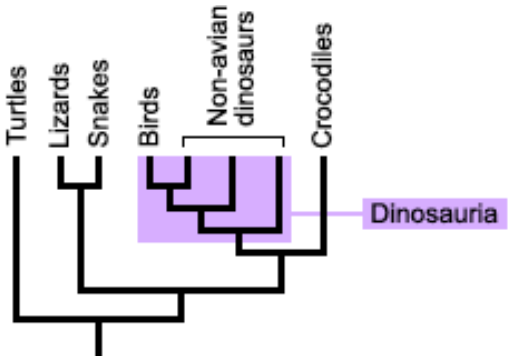
5.4 Cladistics SL

1. What is a clade?

A **clade** is a group of organisms that have evolved from a common ancestor. They will have shared characteristics. They include all the species alive today, their common ancestral species and any species that evolved from it and then became extinct.



Birds all form one clade with thousands of species whereas the tree *Gingko biloba* is the only living member of a clade (there are some extinct members).



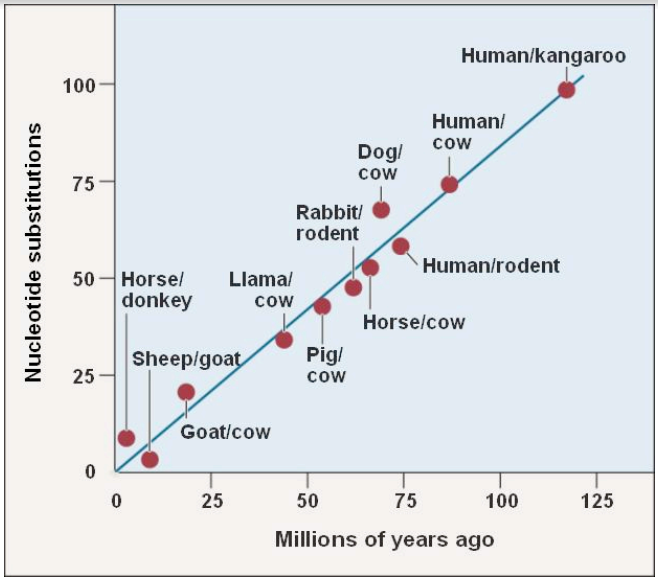
2. What is the EDGE of existence project?

Scientists are identifying species that are sole members of a clade, or perhaps have very few close relatives (i.e. are in very small clades). They then assess their conservation status to see whether they are at risk of extinction. It would be a shame to lose such species. This is the EDGE of existence project.

3. What evidence is used to identify members of a clade?

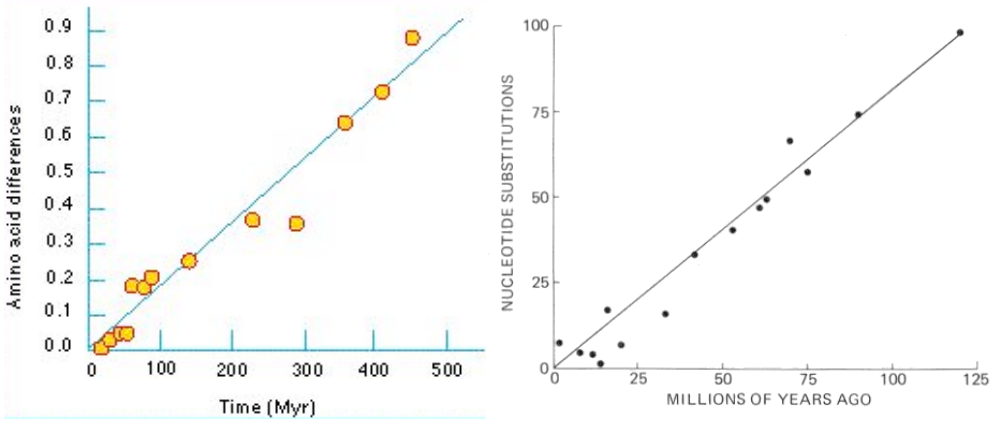
When the sequence of amino acids in a protein such as haemoglobin is compared it is possible to show a common ancestry, because closely related species will have few differences in the sequence. This is also true for the nucleotide base sequences in DNA. Other evidence is common structures but this is less objective and may lead to mistakes.

Homologous structures make good evidence but analogous structures due to convergent evolution lead to mistakes.



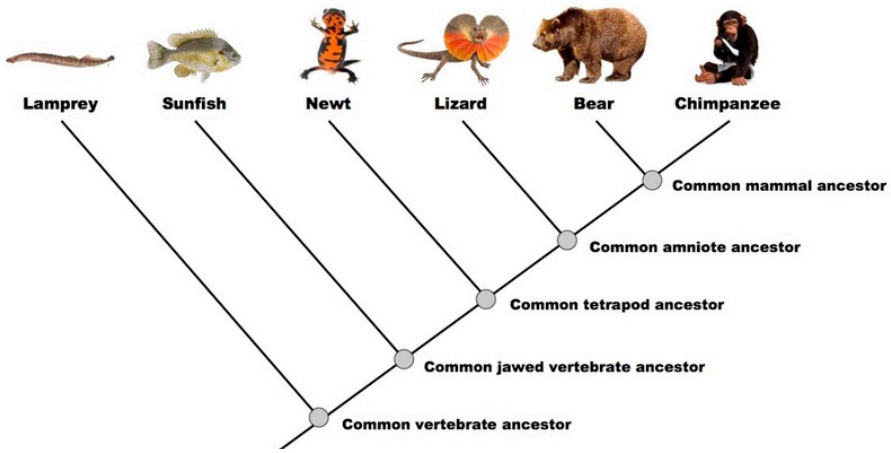
4. What is the molecular clock?

Differences in DNA or amino acid sequences accumulate gradually so there is a correlation between the number of differences between two species and the time since they diverged from a common ancestor.



5. What is a cladogram?

Cladograms are tree diagrams that show the most probable sequence of divergence in clades. Similarities and differences between species are used to construct the tree. Each branching point s called a **node**. The node represents a hypothetical ancestral species that split in a speciation event.



Cladograms can be drawn to scale to show the minimum time needed to diverge, but it is best to compare different cladograms using different genes as evidence. The more nodes that separate two species, the less related they are.

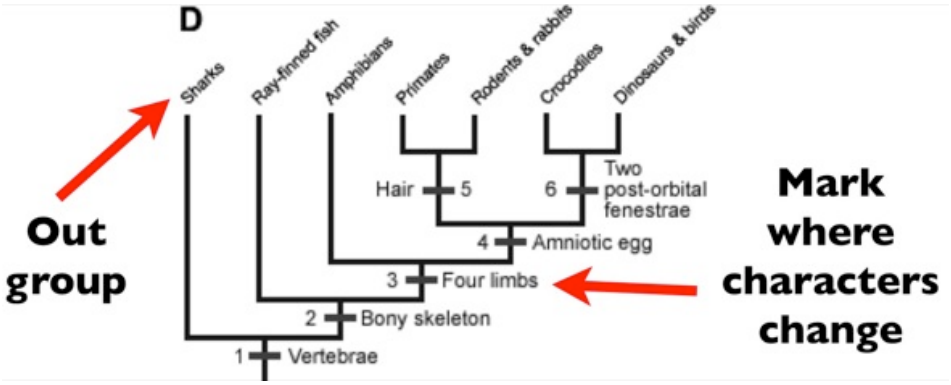
6. What are shared and derived characteristics?

A **shared ancestral character** is a character that originated in an ancestral taxon. It has been inherited and not significantly changed. A **derived character** is an evolutionary novelty unique to a particular clade. It has evolved more recently.

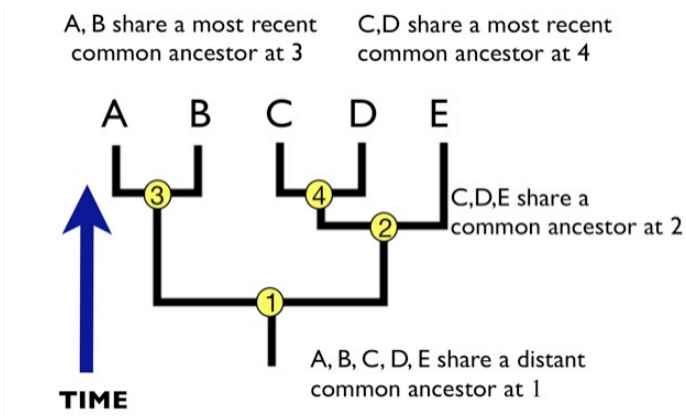
All species are a mixture of ancestral and derived characters. We can use them to form a cladogram. First we collect as much information as possible in a table like that shown below.

Outgroup	Vertebrae?	Bony skeleton?	Four limbs?	Amniotic egg?*	Hair?	Two post-orbital fenestrae?**
Sharks and relatives	YES	no	no	no	no	no
Ray-finned fishes	YES	YES	no	no	no	no
Amphibians	YES	YES	YES	no	no	no
Primates	YES	YES	YES	YES	YES	no
Rodents and rabbits	YES	YES	YES	YES	YES	no
Crocodiles and relatives	YES	YES	YES	YES	no	YES
Dinosaurs and birds	YES	YES	YES	YES	no	YES

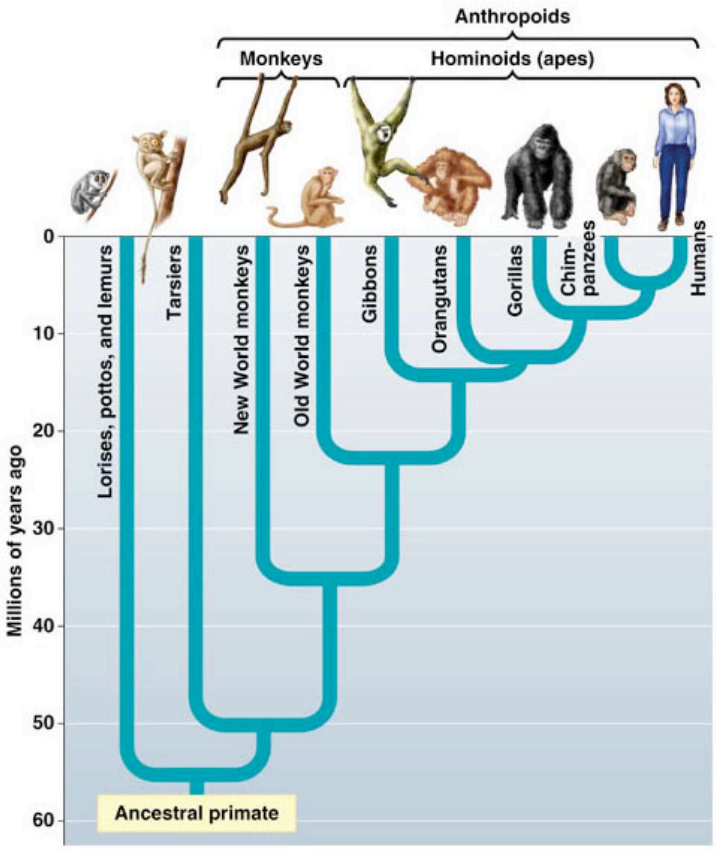
We construct the diagram by grouping organisms with shared characteristics.



7. How do we interpret cladograms?



8. What does the primate cladogram look like?



9. What is cladistics and how has it changed our view of evolution?

Modern computers have allowed the construction of cladograms and identification of clades. This is called **cladistics**.

Cladistics has changed some exisiting classification as it became clear that traditional classification beased on morphology (structures) does not always match the evolutionary origins of groups of species. This is especially true of many plant groups.

10. How has cladistics led to the reclassification of the figwort family?

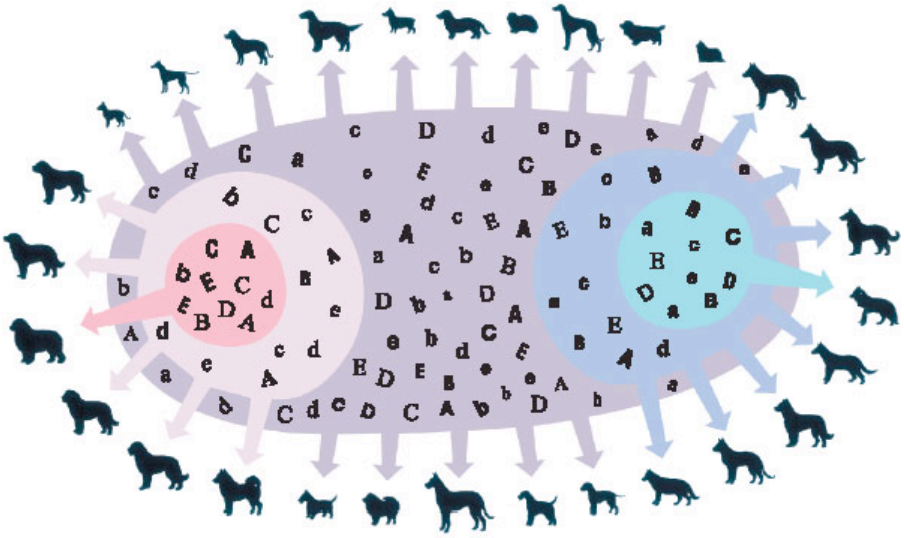
The Figwort family had 275 genera based on morphology but recent DNA analysis of chloroplast genes has shown that 5 clades had been combined into one family. About half the number of species remain in the figwort family.

Such reclassification of plants is an example of falsification of theories in science.

10.3 Gene Pools and Speciation HL

1. What is a gene pool?

A **gene pool** is all the genes and their different alleles, present in an interbreeding population. A species exists as many populations, each with their own gene pool.



2. How does evolution affect allele frequencies?

Evolution changes the frequency of alleles in a population over time.

3. What is genetic fitness?

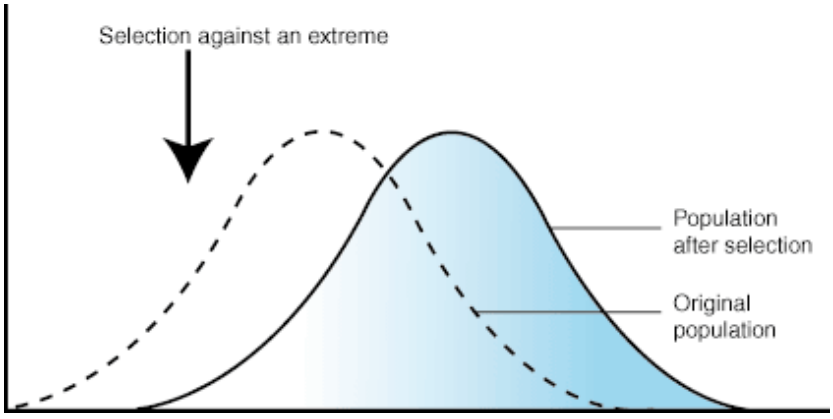
Fitness is the likelihood that a phenotype will be found in the next generation.

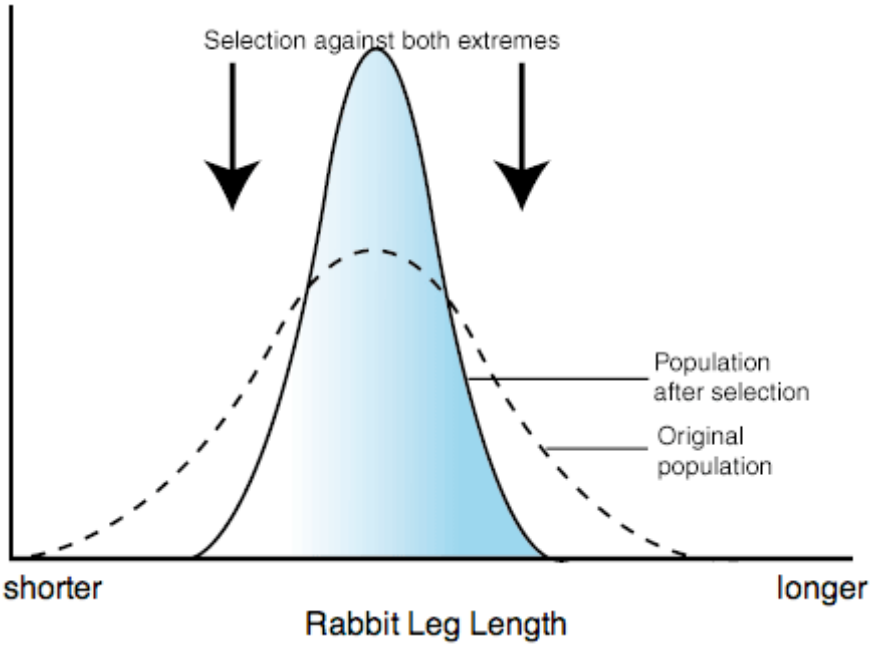
4. What are the three types of selection?

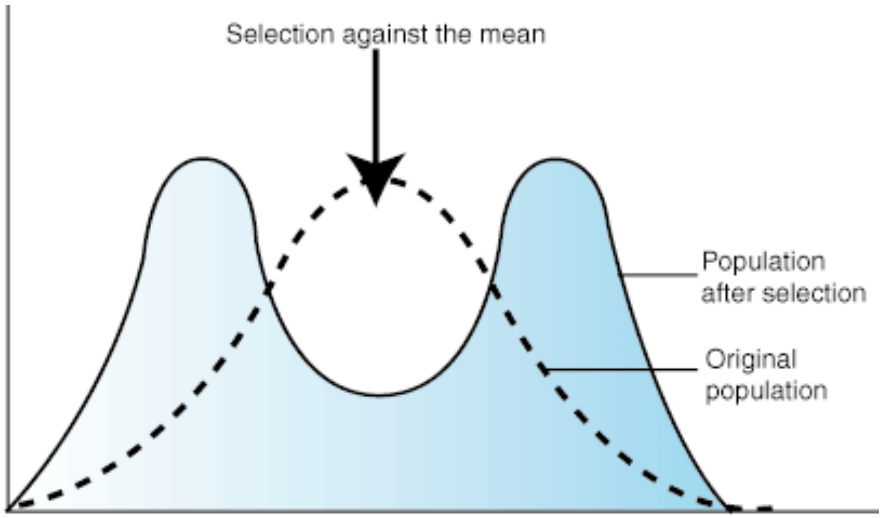
Selection can be **directional** – when one extreme of the range of variation is favoured.

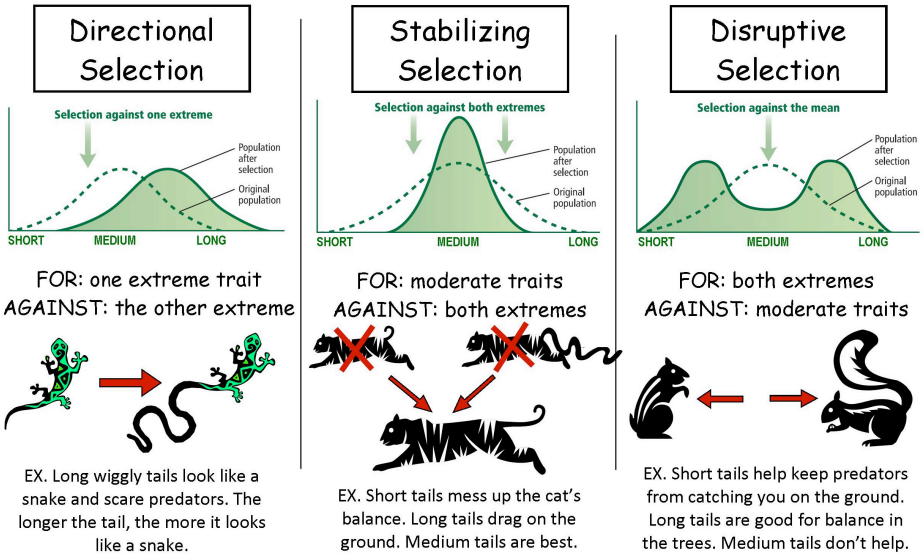
Selection can be **stabilising** – when selection acts to remove extreme varieties. Average human birth weights are favoured over low or high birth weight. This tends to maintain a population.

Selection can be **disruptive** – when selection acts to remove the intermediate varieties, favouring the extremes.




Selection against both extremes
Population after selection
Original population
shorter
longer
Rabbit Leg Length


Selection against the mean
Population after selection
Original population

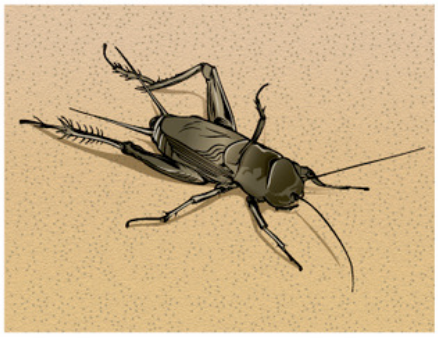

Directional Selection
Selection against one extreme
Population after selection
Original population
SHORT
MEDIUM
LONG
FOR: one extreme trait
AGAINST: the other extreme
EX. Long wiggly tails look like a snake and scare predators. The longer the tail, the more it looks like a snake.
Stabilizing Selection
Selection against both extremes
Population after selection
Original population
SHORT
MEDIUM
LONG
FOR: moderate traits
AGAINST: both extremes
EX. Short tails mess up the cat's balance. Long tails drag on the ground. Medium tails are best.
Disruptive Selection
Selection against the mean
Population after selection
Original population
SHORT
MEDIUM
LONG
FOR: both extremes
AGAINST: moderate traits
EX. Short tails help keep predators from catching you on the ground. Long tails are good for balance in the trees. Medium tails don't help.

5. What is reproductive isolation?

In order for speciation to occur, populations must form a barrier to reproduction. Such reproductive isolation can be temporal, behavioural or habitat.

Some species develop different mating rituals or location. Others breed at different times, such as the frog species below. One breeds January to March, the other from March to May.

Some may inhabit different habitat areas, such as the cricket species below. This isolates them reproductively.



(a) *Gryllus pennsylvanicus* prefers sandy soil.

(b) *Gryllus firmus* prefers loamy soil.

(a) Honeybee drinking nectar from a foxglove flower

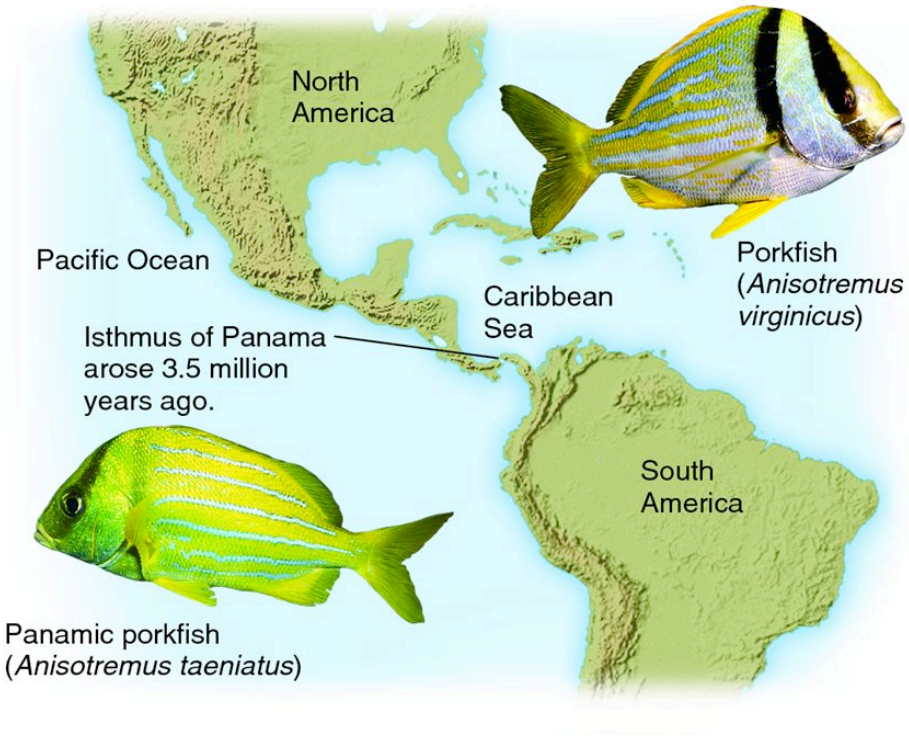
(b) Ruby-throated hummingbird drinking nectar from a trumpet creeper flower

Many plants have evolved to be pollinated by one specific pollinator so isolating them reproductively.

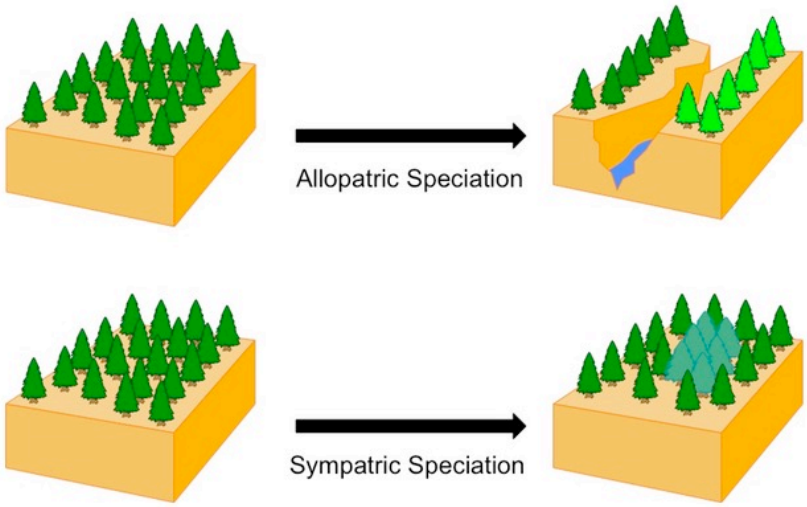
Some have incompatible sex organs (common in insects).

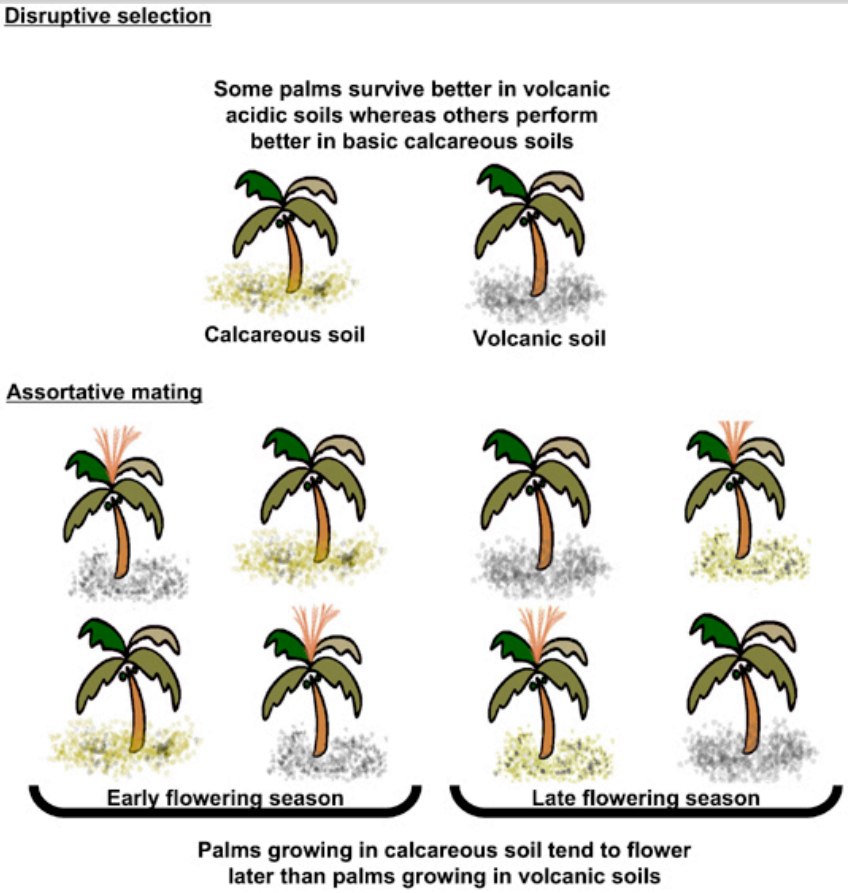
6. What is allopatric and sympatric speciation?

When speciation occurs with geographical isolation then it is called **allopatric speciation**.



When speciation occurs without geographical isolation it is called **sympatric speciation**. It could happen as local variants adapt to local conditions in different ways. It is also more likely when disruptive selection occurs.



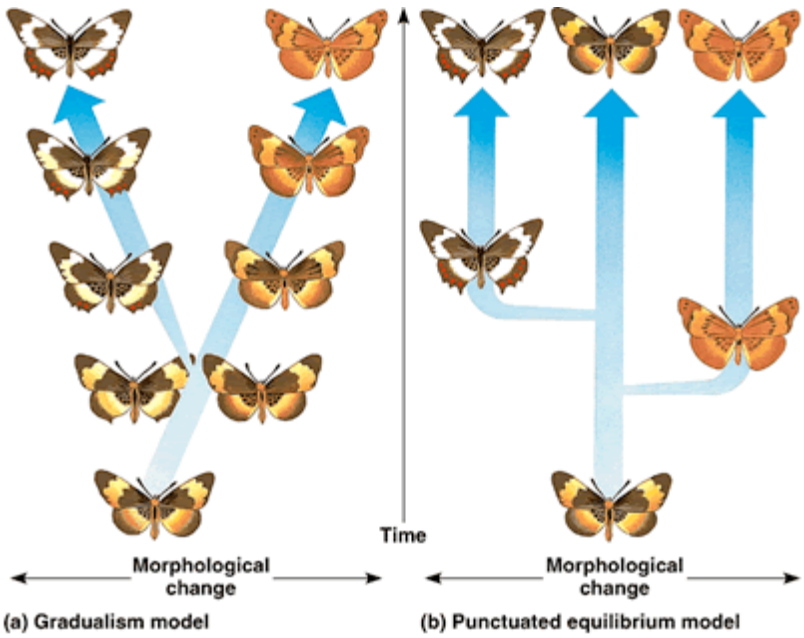


7. What is gradualism?

Gradualism suggests that species change slowly and gradually through a series of intermediate forms. Gaps in the fossil record challenge this idea, as often the intermediate forms are not found.

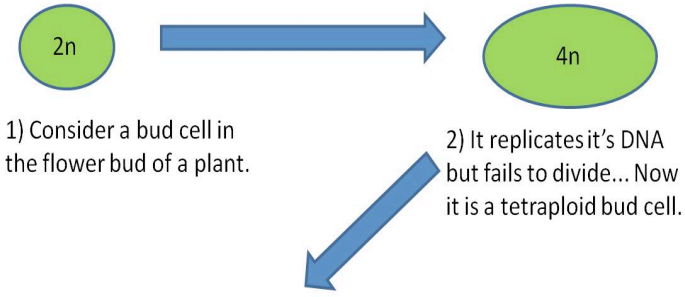
8. What is punctuated equilibrium?

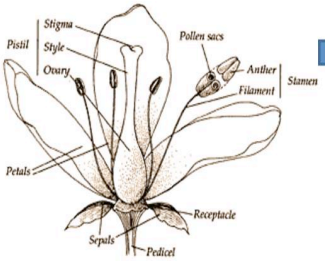
Punctuated equilibrium suggests that long periods of relative stability in a species are "punctuated" by periods of rapid evolution. This idea would not expect to find a series of intermediate steps.



9. What is polyploidy?

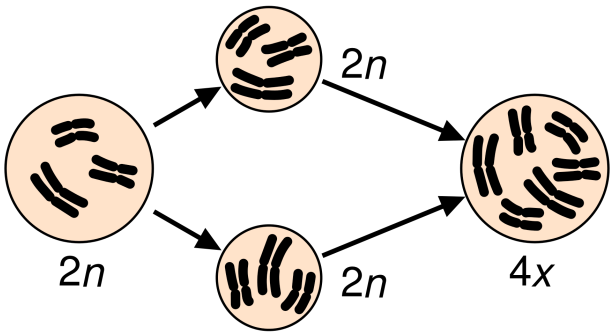
Polyploidy occurs when an organism gets more than two sets of homologous chromosomes. This can be due to failed meiosis leading to a diploid gamete, which can fuse with another diploid gamete of the same species to form a tetraploid organism. This is more common in plants because they can self-pollinate or reproduce asexually. This is sympatric speciation.



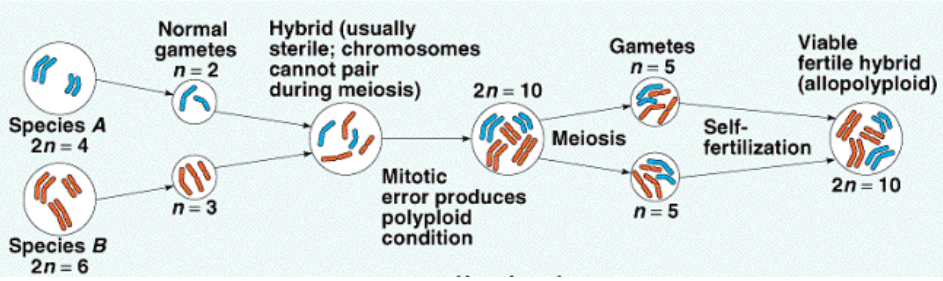


4) If it is self-compatible, it can mate with itself, producing 4n zygotes that develop into a new 4n species.

Why is it a new species?

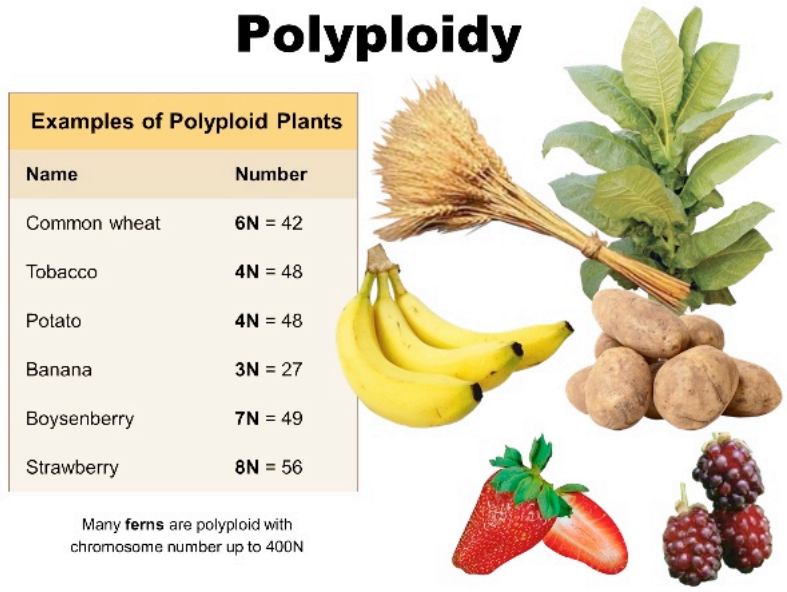


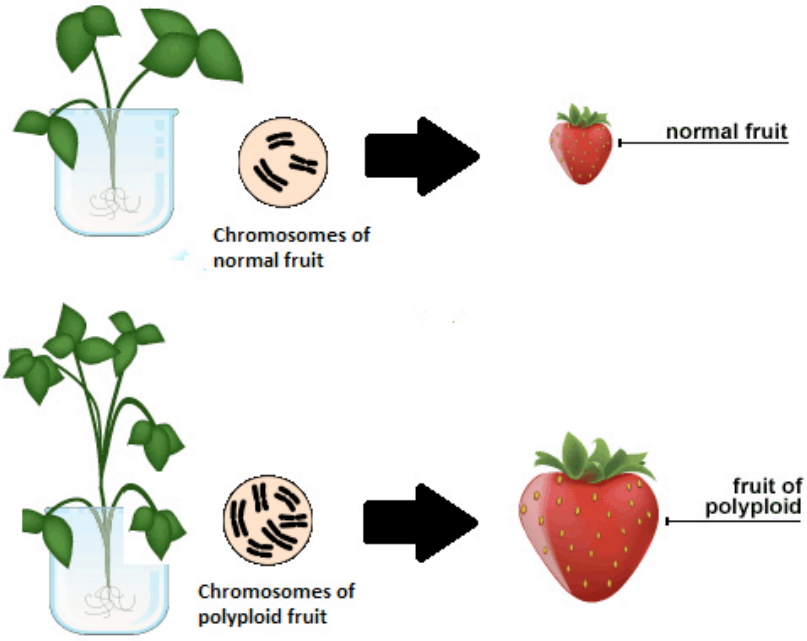
It is also possible that two different species could form a hybrid, which would normally be infertile. However, if the hybrid produced polyploid gametes then they could self-pollinate to make a fertile new species.



10. How do polyploid plants compare to normal plants?

Ploylpoids tend to show hybrid vigour (produce bigger and healthier plants) so they are very common in plants.





11. How has *Allium* evolved by polyploidy?

There are many species within the *Allium* genus due to common polyploidy. They are important food plants including onion, leeks, garlic and chives.