Genetic Variation AS 90948

Achievement Criteria

Biological ideas relating to genetic variation are limited to concepts and processes connected with:

- the continuity of life based on the inheritable nature of DNA
- links between DNA and variation in phenotypes
- variation in phenotypes as adaptive features.

Biological concepts and processes relating to the inheritable nature of DNA will be selected from:

- the roles of DNA in both carrying instructions to the next generation and determining phenotype
- the relationship between DNA, alleles, genes, and chromosomes
- the way in which genotype determines phenotype
- the way chromosomes exist as pairs so that individuals inherit two copies of each gene.

Biological concepts and processes relating to variation in phenotype will be selected from:

- the significance of an allele as an alternative version of a gene
- the role of mutations in forming new alleles
- the role of meiosis in generating gametes (students are not required to provide the names of the stages of meiosis)
- the significance of sexual reproduction (in producing a new mix of alleles)
- the patterns of inheritance involving simple monohybrid inheritance showing complete dominance, sex determination, possible genotypes, and phenotype ratios.

Biological concepts and processes relating to variation in phenotypes as adaptive features will be selected from:

- inheritable and non-inheritable variations that exist within a group of living organisms
- differing rates of survival by various members of a group may depend on their phenotype
- the importance of variation within populations (population and species survival) in a changing environment such as pest infestation, disease, drought, or flood
- the advantages and disadvantages of sexual reproduction.

The student must be familiar with the following genetic language and conventions: gene, allele, mutation, genotype, phenotype, gamete, zygote, dominant, recessive, homozygous, heterozygous, pure breeding, Punnett square, and pedigree chart.

Genes are the sources of inherited information

All living things are made of cells. The nucleus of a cell contains chromosomes, which carry instructions for the growth and development of an organism. The chromosomes are made of long strands of DNA. The order of molecules on the DNA strand code for protein. The instructions are called the genetic code. A segment of the DNA that codes for a specific protein is called a gene.

Genes are 'coded instructions' for making proteins and that DNA is the chemical, which stores the coded instructions

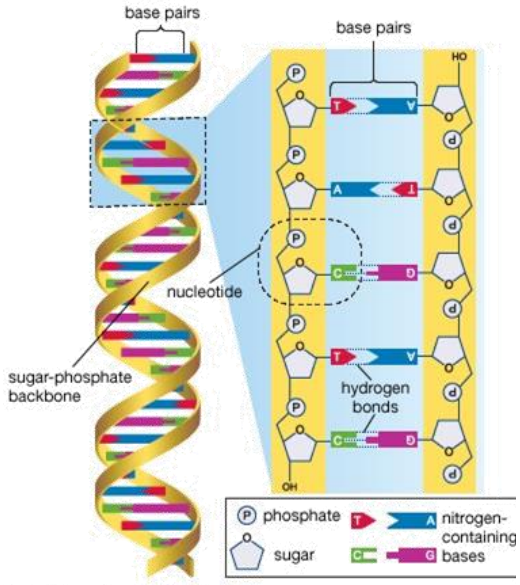
DNA is arranged in a double helix shape. The up rights of the "ladder" consist of alternating sugar and phosphate molecules bonded together. Making up the "rungs" are two base molecules connected to each sugar molecule. The base molecules are held together by hydrogen bonding which can be broken and then later reformed when the DNA molecule splits to make a copy for protein manufacture or DNA replication.

DNA (deoxyribonucleic acid) units are called nucleotides, which consist of a sugar, a triphosphate and a base.

There are four bases

A – Adenine
C – Cytosine
G - Guanine
T – Thymine

You do not need to know the names of the bases, only the letters. The DNA nucleotides join together to form a long ladder, which spirals into a double helix.



G bonds with C

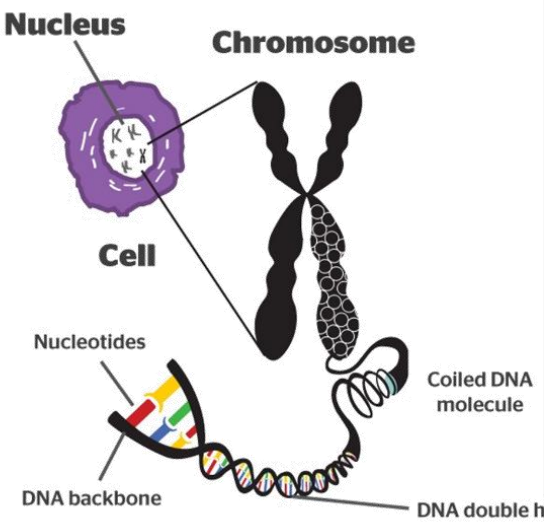
A bonds with T

This is called the complimentary base-pairing rule. The order of these bases is the code for producing specific proteins.

DNA Structure summary

- ❑ DNA is made up of a series of nucleotides, each consisting of a sugar (deoxyribose) and base and a phosphate.
- ❑ DNA has four bases; A bonds to T and C bonds to G
- ❑ DNA is a double stranded helix that can separate during replication to produce two identical strands that allow DNA to be passed onto another cell or gamete.
- ❑ The base pairing rule makes DNA a stable molecule with less chance of mutation
- ❑ The sequence of bases coding for a specific proteins, leading onto a trait, is called a gene.

Chromosomes are found in the nucleus and genes are carried on chromosomes

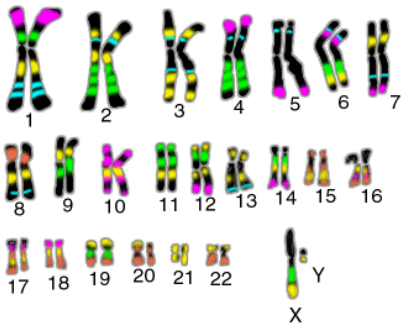


Chromosomes are found in the nucleus and genes are carried on chromosomes

DNA strands are loose within the nucleus of a cell. Just prior to cell division the DNA folds up around proteins called histones into tight coils, then into structured chromosomes. The human cell has 46 chromosomes arranged into 23 pairs of chromosomes. Each chromosome in a pair has the same genes, called homologous pairs – except the sex chromosome pair – although there may be variation between the genes of each pair, as one comes from the father and one comes from the mother.

Human Karyotype

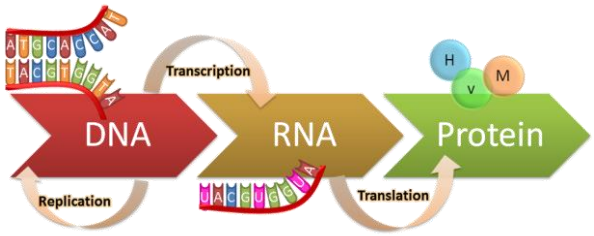
A complete set of chromosomes of an organism placed into pairs of matching chromosomes is called a karyotype. The human karyotype consists of 23 pairs of chromosomes. One pair is the sex chromosomes – XX in females and XY in males.



Other species may have a different number of chromosomes in each cell compared to Humans. The number of chromosomes do not relate to the "complexity" of the organism.

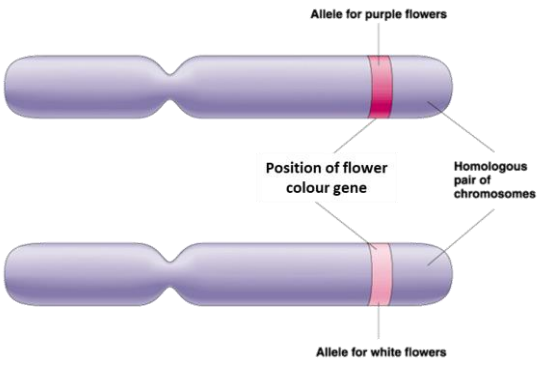
"Making protein" (EXTENSION)

The order that the bases are arranged in the DNA segment of a gene determine the type of protein that will be formed. The bases are "read" in sets of three called codons. Codons are matched to molecules called amino acids, which are the building blocks of proteins.



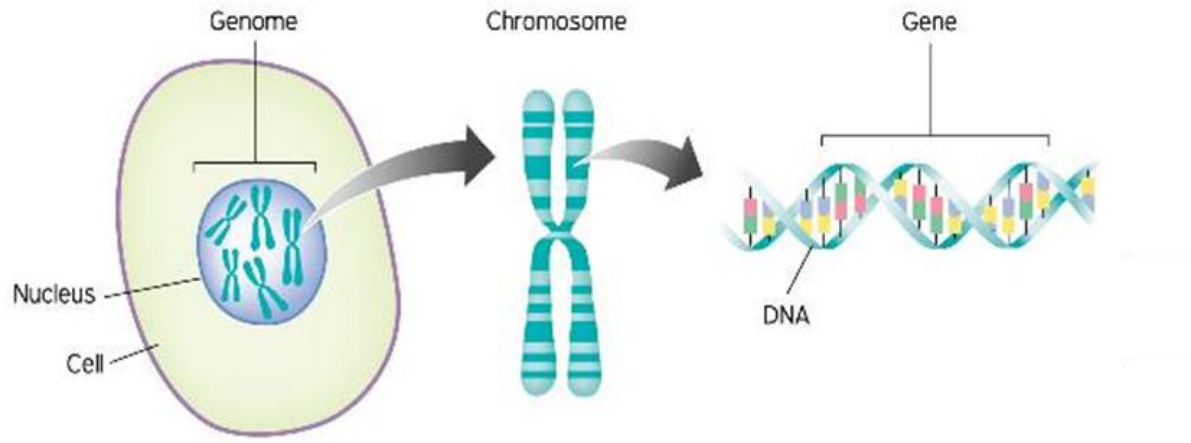
Alleles

Chromosomes occur in homologous pairs. These pairs of chromosomes have the same genes in them at the same place (loci). The versions of genes are called alleles and may be different from each other. When the genes are being expressed only allele needs to be used.



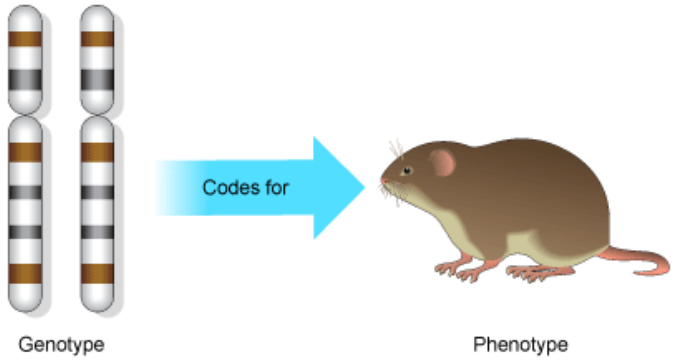
Writing linking explanations between the nucleus, Chromosomes, DNA, genes and alleles

All living things are made of cells. The nucleus of a cell contains chromosomes, which carry instructions for the growth and development of an organism. The chromosomes are made of long strands of DNA. The order of molecules on the DNA strand code for traits/protein. The instructions are called the genetic code. A segment of the DNA that codes for a specific trait/protein is called a gene. Each gene is represented by two alleles, which are different varieties. The alleles can be the same or different but the body only selects one to express.

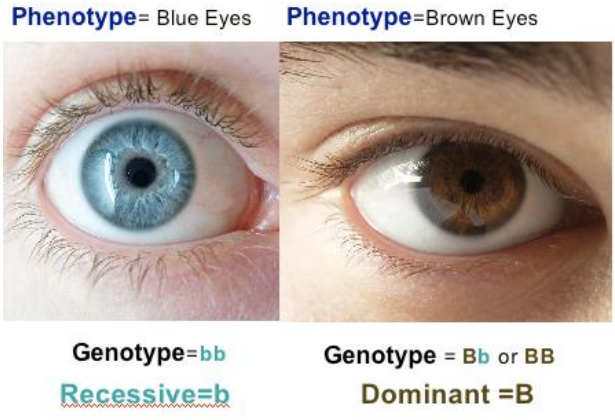


Phenotype and genotype

The genotype is the combination of alleles that an organism contains for a trait on its two homologous chromosomes. For any particular trait they can be heterozygous (different) or homozygous (same). The phenotype is the physical trait that results because of the particular combination of alleles (genotype)

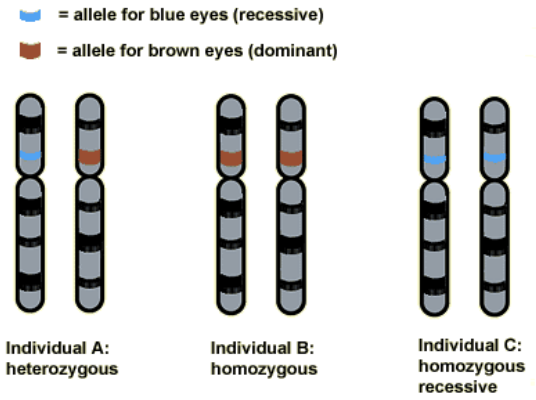


When the phenotype is recessive then the genotype can only be homozygous recessive as well. If the phenotype is dominant then the genotype can either be heterozygous or homozygous dominant, as long as one dominant allele is present in the genotype.

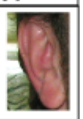
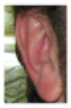
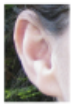


Dominant and recessive genes

The allele that is expressed as a trait when there is at least one allele is called the dominant allele. The allele that is expressed if a dominant allele is not present is called the recessive allele. When there are two of the same alleles, this genotype is called homozygous. When there are two different alleles in a genotype, this is called heterozygous. The dominant allele is always expressed.



Many letters can be used to represent dominant or recessive, such as Bb, Ee, Ff as long as the upper and lower case letters look different. The genotype determines the phenotype.

Genotype	Phenotype
EE Homozygous dominant	Detached Earlobes 
Ee Heterozygous	Detached Earlobes 
ee Homozygous recessive	Attached Earlobes 

Lop eared rabbits – an example

Rabbit ears normally point straight up. Some rabbits have an allele for lop ears that cause the ears fold down. The allele that produces lop ears is recessive and was created by a mutation.

We can use the symbol R to show the dominant allele and r to show the recessive allele.

The genotype of the two rabbits if both are pure breeding are:

Lop eared rabbit genotype rr

Normal eared rabbit genotype RR

lop eared rabbit

straight eared rabbit

Putting it all together – Genetics Vocabulary

Chromosomes are made up of DNA. DNA is a large molecule that is coiled into a double helix (twisted ladder structure). It is responsible for determining the phenotype of an organism. Along this molecule are bases. These bases pair up; A always pairs with T, and G with C.

A sequence of bases, which codes for a particular trait (e.g., eye colour), is called a gene.

The different versions of each gene are called alleles, and these show the different variations of each characteristic, e.g. brown / blue eyes. Because chromosomes come in pairs for each trait, there will be two possible alleles. These different versions of genes (alleles) occur, as the DNA base sequence is different.

This combination of alleles for each trait is called the genotype; this can be any combination of two of the available alleles. The genotype determines the phenotype (the physical appearance) of the organism. Whichever alleles are present may be expressed. Dominant alleles (B) will be expressed over recessive alleles (b).

Genotype and Phenotype – Rock pocket Mice Example

In rock pocket mice, dark fur colour (D) is dominant to light fur colour (d). Each mouse has two alleles for fur colour. They inherit these two alleles, and the two alleles interact to produce different phenotypes.

Phenotype is the appearance of a trait, e.g. dark or light fur. Genotype is the code for the alleles present for the gene. Each mouse receives one copy of each gene from each of its parents during fertilisation, one from the sperm and one from the egg, and so has two copies of each. If either of these are the dominant allele (i.e. DD or Dd), the mouse will be dark, as the dark allele is dominant (and so masks the light allele). If both are recessive (dd), the mouse will be light.

Light colour

https://inaturalist.org

Dark colour

Using Punnett squares to predict offspring

We use Punnett squares to keep track of alleles when calculating the genotype of any offspring created when two organisms are mated

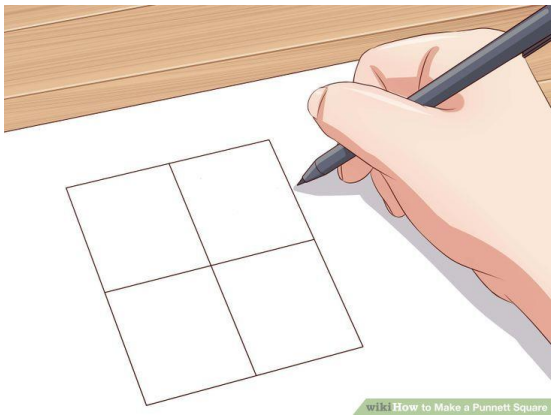
Agouti Rabbit

Black Rabbit

	B	b
b	Bb	bb
b	Bb	bb

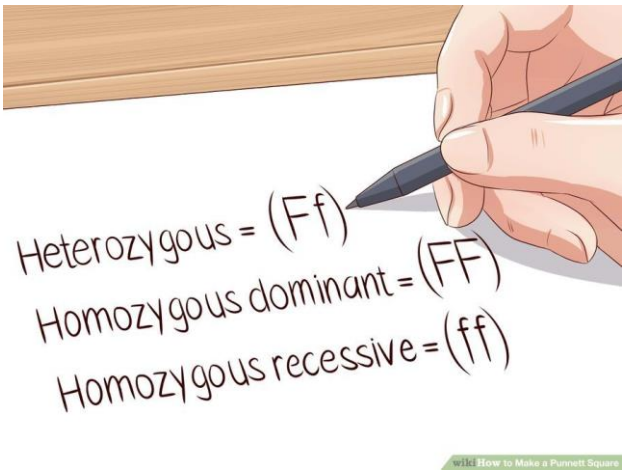
How to use a Punnett squares to predict offspring

1. Draw a grid with 4 squares. Each square will represent 1 out of 4 offspring or 25% of offspring out of 100%

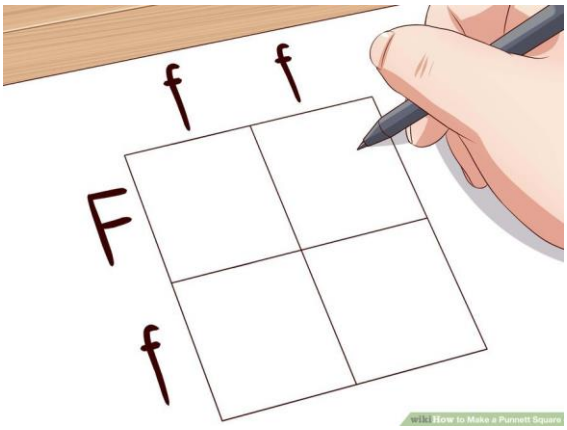


2. Write down the possible 2 phenotypes (physical traits) and label them with a capital letter for the dominant trait and lower case letter for the recessive trait.

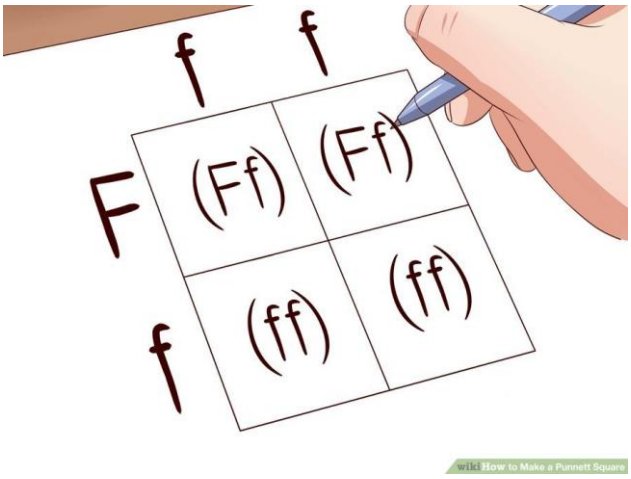
3. Write down all 3 possible genotypes and their letter combinations.



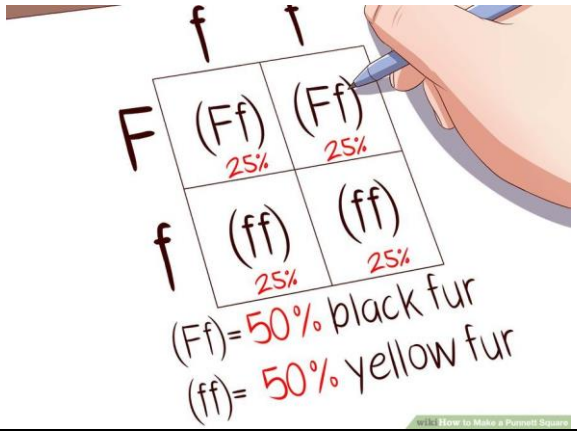
4. Select the correct genotypes for each parent (they may be the same or different) and write them with one parent on the top and one parent to the left side.



5. Write each letter in the square below for one parent and squares to the right for the other parent. Each offspring will have a genotype of 2 letters.



6. Calculate the genotype ratio – the total percentage each genotype occurs (in this order FF: Ff : ff) or total out of 4 squares.
Then calculate phenotype ratio – FF and Ff count as dominant and only ff counts as recessive (in this order dominant : recessive) can be % or out of 4



Using Punnett squares to predict offspring

The Punnett square is used to predict the probability of what the offspring's phenotype and genotype will be, which may or may not match up to the actual results due to the random nature of each fertilisation.

The phenotype and genotype ratios are only predictions.

Each time a new offspring is created through fertilisation it is a new event and the same probabilities apply regardless of the phenotype or genotype of previous

Calculating Phenotype and genotype ratios

We can use the example of our straight eared and lop eared rabbit again when they breed, and all their offspring will have the genotype of Rr and phenotype of straight ears. If we cross two of their offspring (Rr) the genotype and phenotype ratios of their offspring, (second generation) can be set out as below.

	R	r
R	RR	Rr
r	Rr	rr

Genotype Ratios		
RR	Rr	rr
1	2	1
Phenotype Ratios		
Straight Ears	Lop ears	
3	**1**	

Phenotype and Genotype ratios

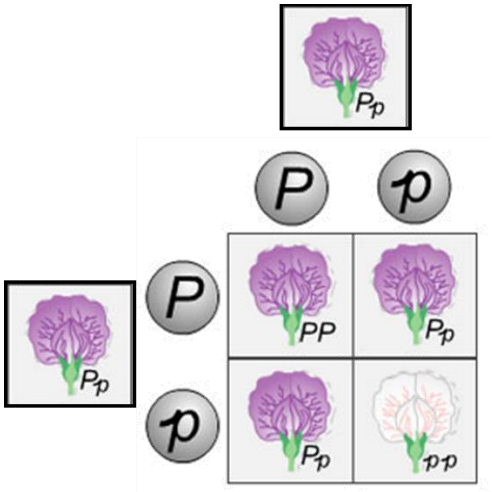
Genotype ratios when crossing two heterozygous parents are always 1:2:1.

That is 1 dominant homozygous: 2 heterozygous : 1 homozygous recessive. They are always written in that order i.e. PP:Pp:pp

Genotype ratios when crossing one dominant homozygous and one recessive homozygous are always 0:4:0 with 100% of the offspring being heterozygous.

Phenotype ratios

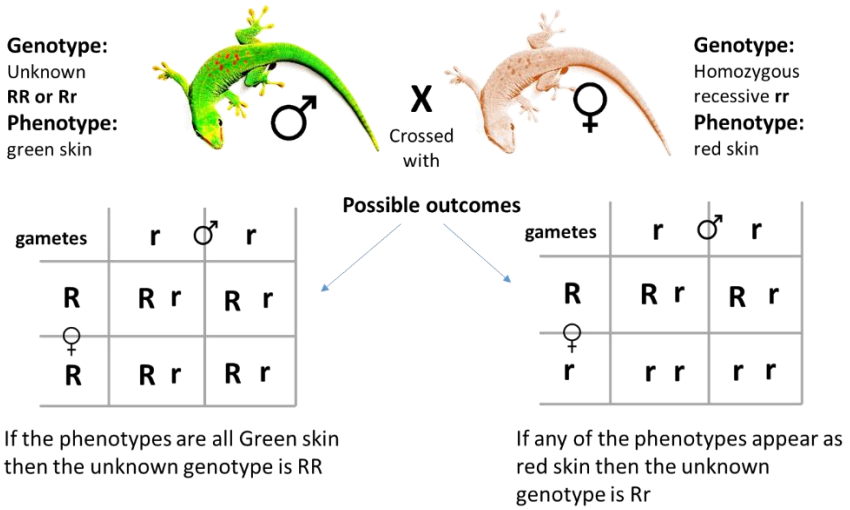
Will always be written as dominant: recessive. Remember both PP and Pp will have the dominant phenotypes and only pp will have the recessive phenotype.



Pure Breeding and test Crosses

An individual that is pure breeding has a homozygous (two of each allele) genotype. The pure breeding recessive homozygous can be seen by its phenotype – it will show the recessive phenotype. The pure breeding dominant homozygous has the same phenotype as a heterozygous individual however. The pure breeding dominant individual can be found by a test cross which it mates with a recessive phenotype individual. If any of the offspring have the recessive phenotype then the individual is not pure breeding.

In order to establish a pure breeding population the test cross must be repeated many times. If the tested parent is not pure breeding then an estimated 50% of the offspring will show up with the recessive phenotype but a small sample size may not show this with just one cross. Non-pure breeding heterozygous individuals must be continuously removed from the population and not be allowed to breed further.

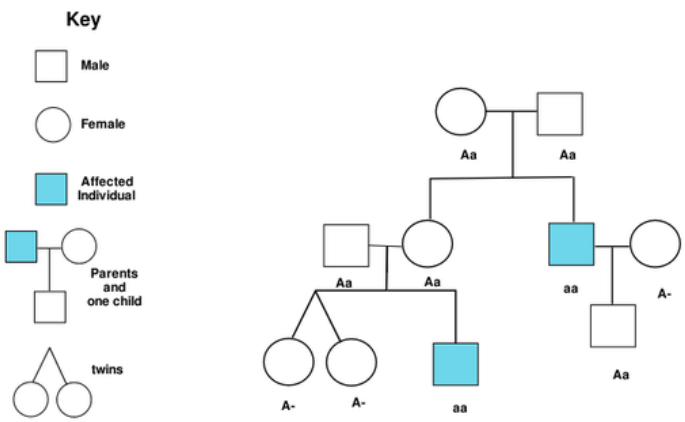


Using Punnett squares to predict the Parent's genotype

Parent's genotypes can be predicted by the phenotype of the offspring. If 100% of the offspring show the dominant phenotype then at least one of the parents must be homozygous dominant. If any of the offspring show the recessive phenotype then each parent must contain at least one recessive allele each in order to have offspring that has a recessive allele donated from each parent. If the parents show the dominant phenotype then they must be heterozygous.

Pedigree charts

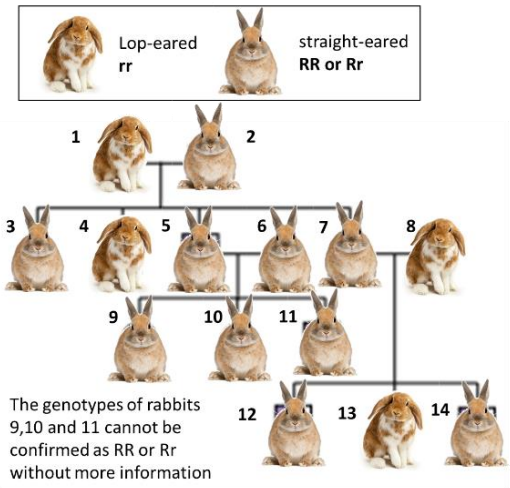
A pedigree chart is a diagram that shows inheritance patterns of a certain trait (Phenotype). A square represents a male and a circle represents a female. If a person's symbol is shaded in, this means that they have the phenotype (in this case, it is a recessive phenotype). If they are not shaded, they do not have the trait and their genotype can be either homozygous dominant or heterozygous. Pedigrees are good for showing the patterns of a recessive or dominant gene.



Using Pedigree charts to predict genotype

When an individual has a recessive phenotype on a pedigree chart then the genotype must always be homozygous recessive (i.e. rr for the lop-eared rabbit 1)

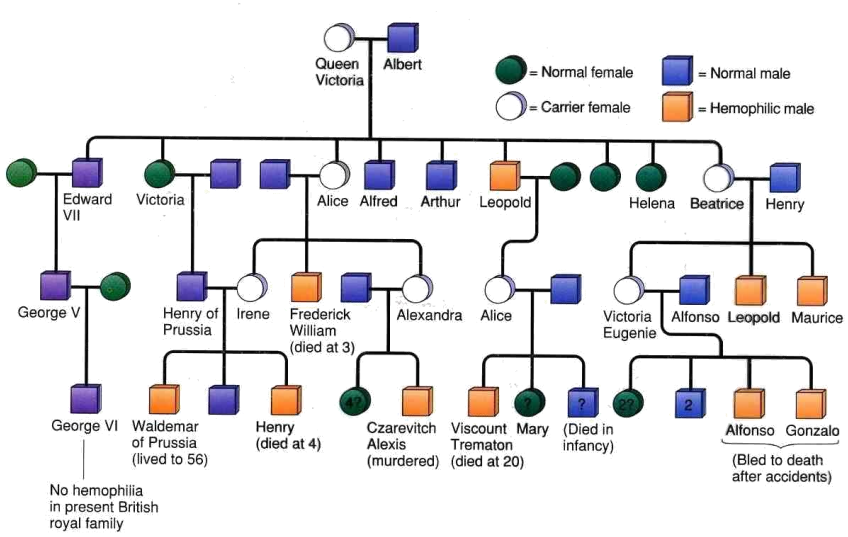
To find out the genotype of a dominant phenotype you can look at either the parents of the offspring. (i.e. rabbit 7 is straight eared but had one parent who was a lop-eared rr so must have one r allele – genotype Rr. Also 13 is an rr (see above) so rabbit 7 must have at least one r allele to pass onto 13.



Using Pedigree charts to predict genetic disorders in offspring

A pedigree chart can be used to predict the likelihood of offspring receiving a mutation from parents as well as look for where the mutation has come from.

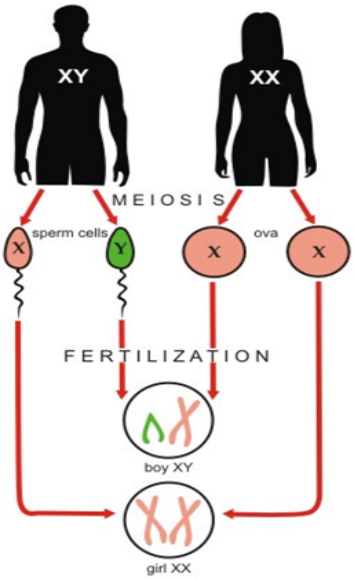
A particularly famous pedigree of a mutation in family comes from the European royal family. The mutation is haemophilia (which prevents clotting of the blood) and can be traced from Queen Victoria



Sex determination

A pair of chromosomes are called the sex chromosomes. The female always has a homologous pair of two x chromosomes. The female can only donate an x chromosome. The male has an x and y chromosome. He can donate either an x or y chromosome to form a gamete. The male determines the gender of any children.

Each offspring receives one copy of each chromosome from each of its parents during fertilisation, one from the sperm and one from the egg, and so has two copies of each.

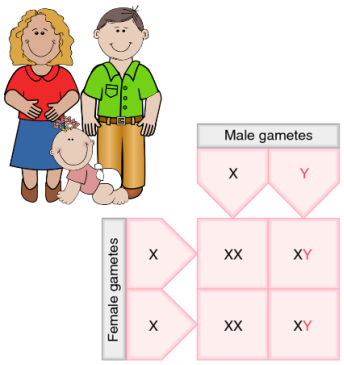


Sex determination

A Punnett square can be used to demonstrate that in any fertilization there will be a 50% chance of either a boy or a girl.

If there are a small number of offspring then there is less chance that the actual ratio of male to female offspring will be the same as the predicted ratio.

Each new fertilisation is independent of any previous fertilizations'. Regardless of how many boys or girls have been produced previously in a family, each new child has a 50:50 of being a boy or girl.



Species show genetic variation

Organisms of a species that reproduce sexually are not identical therefore, they exhibit variation. Variation or differences in traits are caused by genetic factors (what genes you are born with) and environmental factors but only genetic variation can be passed onto the next generation.

Human Variation

As a species, Humans all have the same set of genes. However, each individual, except identical twins, has a different combination of alleles inherited from both parents and this creates variation. Variation of traits causes each individual to look different from another and in many cases behave differently from each other as well.

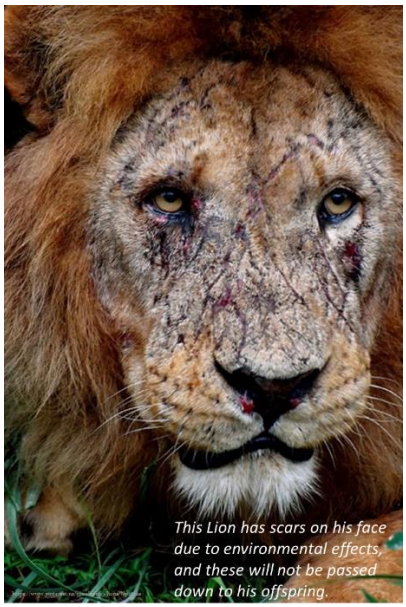
An individual within an ethnic group tends to have more similar traits in common to others within the same group.

Inherited and Environmental Variation

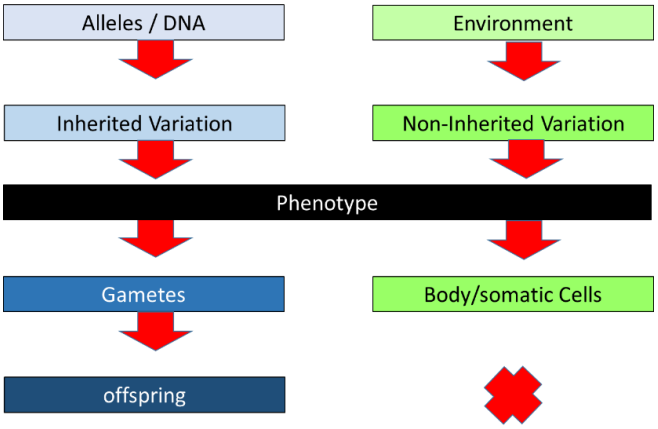
Many traits that determine our appearance have been inherited from our parents. Every single cell in our bodies will contain a copy of the alleles that are responsible for these inherited traits and these can be passed down to our children.

However, some variation can be acquired during our lifetime from environmental effects such as smaller size due to lack of food while growing or loss of sight due to injury. This variation will not be passed on to offspring.

Inheritable variation can be passed on to offspring, involves a change / mutation / information in the DNA, whereas non-inheritable variation may be due to the environment (or only occurs in body cells), and so affects only that organism, not its offspring.



Inherited and Non-inherited Variation



Environmental Variation – Hydrangea Case study

Colour variation in hydrangeas is determined by the environment and is due to the presence or absence of aluminium compounds in the flowers. If aluminium is present, the colour is blue. If it is present in small quantities, the colour is variable between pink and blue. If aluminium is absent, the flowers are pink.

Soil pH (acid or base) indirectly changes flower colour by affecting the availability of aluminium in the soil. When the soil is acidic (pH 5.5 or lower), aluminium is more available to the roots, resulting in blue flowers.

Continuous and discontinuous variation

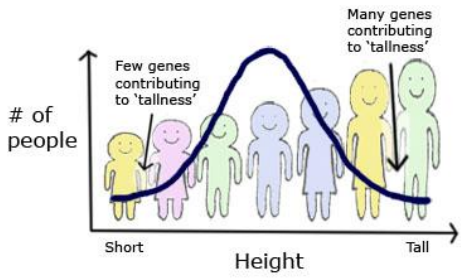
Inherited variation of a trait in an individual can be continuous such as tallness where height can be either very tall or very short as well as any height in between. Offspring will most often show height half way between the two parents as alleles inherited from both parents have a combined effect.

Variation of a trait can also be discontinuous such as the ability to roll your tongue. You can either roll it or you cannot but you cannot not half roll it. Offspring will inherit their trait from one parent or the other but not both.

Continuous Variation

A group of genes creates traits that cause continuous variation. When random groups of people are measured for a particular trait the extremes tend to be expressed the least and the mid-point tends to be expressed the most. This creates a bell shaped curve when graphed.

In the example below, many more people tend to be of average height compared to being very short or very tall.



Discontinuous Variation

Discontinuous Variation produces an "either/or" trait (physical characteristic).

Every person inherits one allele (a version of a gene producing the trait) from each parent. This gives the person two alleles for each trait (their genotype)

If a person has one or two dominant alleles then they will also have the dominant phenotype (trait). A person can only have the recessive phenotype (trait) if they have two recessive alleles.

Examples of inherited Traits for Discontinuous Variation

Dominant phenotype (trait)	Recessive phenotype (trait)
Cleft Chin	No Cleft
Widow's Peak	No Widow's Peak
Dimples	No Dimples
Brown/Black Hair	Blonde Hair
Freckles	No Freckles
Brown Eyes	Gray/Blue Eyes
Free Earlobe	Attached Earlobe

Variation occurs due to the processes of Mutation, Meiosis and Sexual reproduction

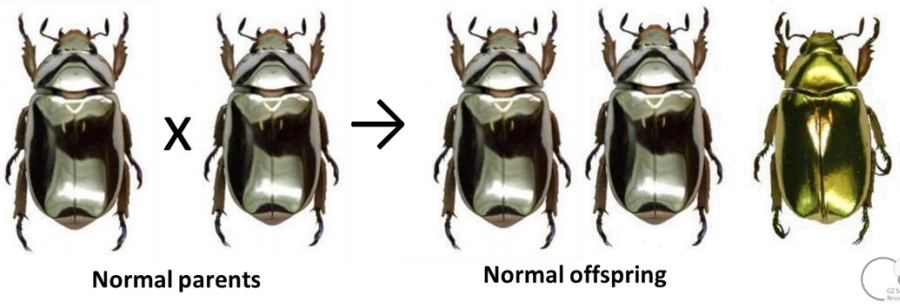
Three main processes cause variation between parents and their offspring. Each of these processes either introduces new alleles (mutation) into the offspring or mixes up the combination of alleles received from the parents (meiosis and sexual reproduction) to ensure each individual offspring has a different assortment of alleles while still receiving the complete set of genes required.

- ❑ Mutation
- ❑ Meiosis (independent assortment and crossing over)
- ❑ Sexual reproduction

Mutations introduce new alleles into a population

Most mutations cause death because the gene in which the mutation occurs creates an incorrect protein. Very occasionally, mutations produce a new type of protein, which gives the organism an advantage over others in its species in adapting to its environment. The organism containing the mutation will have more chance of surviving than those individuals without it and it will pass the mutated gene on to the next generation more successfully.

Mutations increase variation in a population by adding new types of alleles.



Normal parents **Normal offspring**

Mutations can occur either in individual cells of an organism such as cancer or in the gametes (egg and sperm cells) which causes every cell in the developing offspring produced to contain the mutation.

Only mutations that occur in the gametes (usually during the process of meiosis) can be inherited by the next generation. It may not be expressed (seen as a physical trait) in the offspring if the mutation is recessive and the other parent has a unaffected allele but if it is dominant then every individual offspring will express the trait (produce the mutated protein).

Mutations that occur in an adult's body cells (somatic cells) will not be inherited by offspring.

Humans can have specific genetic disorders caused by a mutation

Genetic disorders are passed down from the parents' genes. Some disorders occur through a mutation in an entire chromosome (or the addition of an extra chromosome) and cause a syndrome with many different parts of the body effected, such as Down syndrome. Other disorders are a mutation to only one part of a gene and cause a single change like sickle-cell anaemia does to the shape of red blood cells.

Mutation Summary

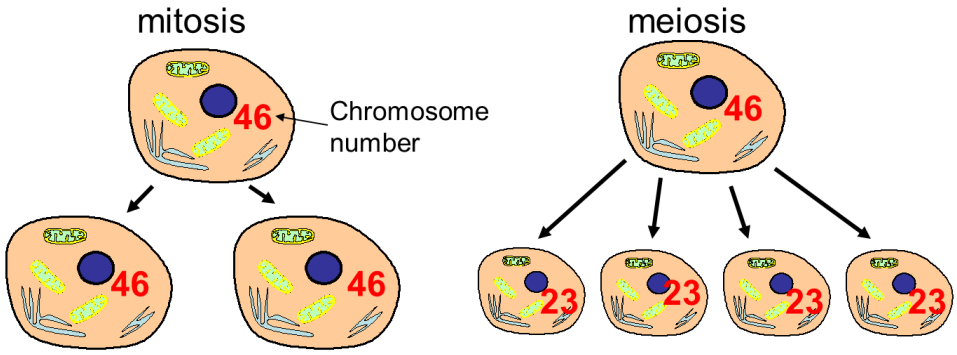
- A mutation is a permanent change in the base sequence of a DNA strand, either single bases or segments of chromosomes.
- A base sequence change can result in the formation of new alleles.
- A new allele can code for a new protein that leads onto a new trait.
- A organism with a mutation may have a new structure or function and as a result will have a new phenotype.
- Most mutations are harmful, which reduce the chance of survival or reproduction.
- Some new phenotypes (mutation) may increase an organism's chances of survival or successful reproduction. A mutated allele that increases survival/reproduction will increase in frequency rapidly in a population.

Mitosis and Meiosis

Cells divide for growth and/or repair – called mitosis and for the production of gametes – called meiosis.

Mitosis creates two identical daughter cells from each parent cell. Each of these cells maintains a full set of identical chromosomes (diploid). These cells are called somatic cells.

Meiosis divides one parent cell into four gamete cells. Each gamete has half the number of chromosome of the parent cell (haploid). A male and a female gamete recombine during fertilisation to form a cell with the complete set of chromosomes.



Meiosis creates gametes with variation

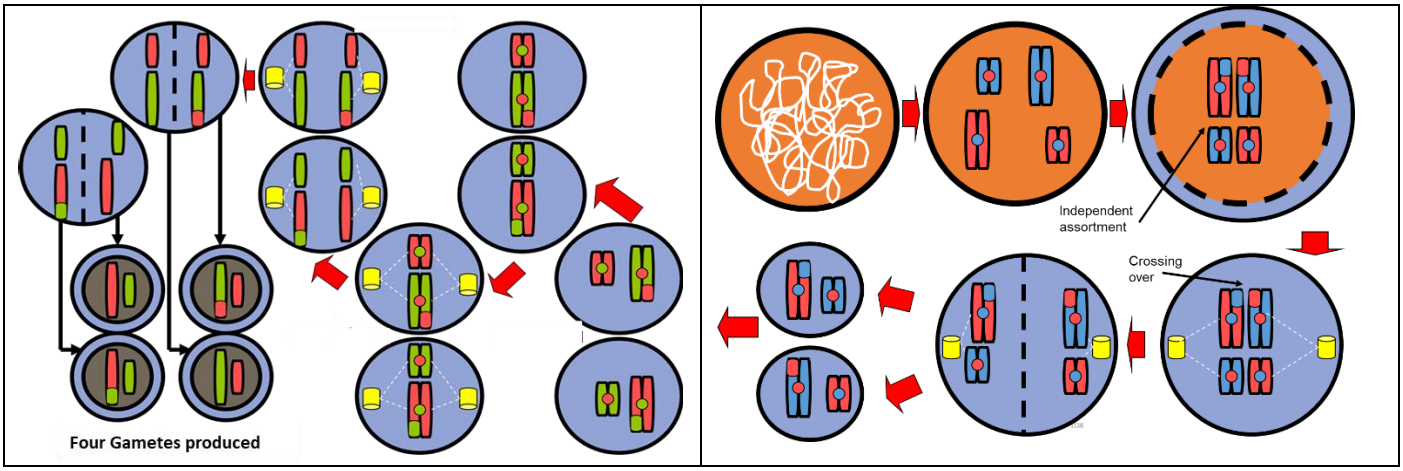
During Meiosis, there are two opportunities for increased variation.

Firstly, when the homologous pairs line up. It is different each time meiosis occurs as one chromosome from each pair will go to each new gamete (called independent assortment) – and each contains a different collection of alleles (although they both have the same genes).

Secondly, portions from each homologous pair swap (called crossing over) creating different combinations of alleles in once identical copies. Another opportunity for variation occurs during fertilisation when any male gamete can combine with any female gamete randomly.

Meiosis creates gametes with variation – Stages of Meiosis

You are not required to provide the names of the stages of meiosis



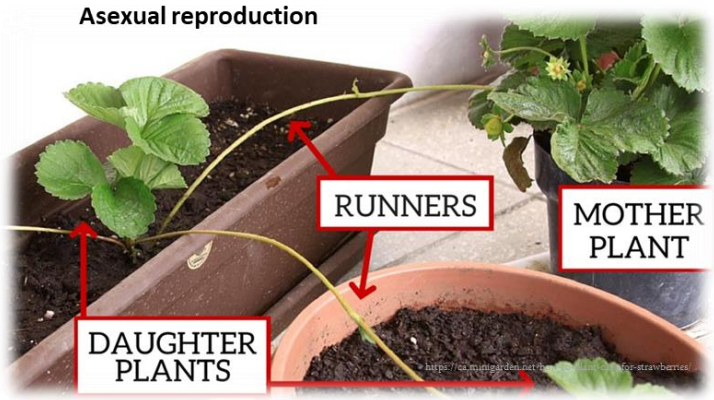
Reproduction

All organisms need to reproduce; to create offspring that carry their genetic information, as part of the life processes that defines them as living.

Some organisms reproduce sexually, and together with a mate of the same species produce offspring that have a combination of both parents genetic material. The offspring from sexual reproduction will show variation in their traits.

Other organisms are able to reproduce asexually, with no mate required and all of their offspring will have identical genetic material to their parents with no variation seen.

Some species can reproduce using both methods.



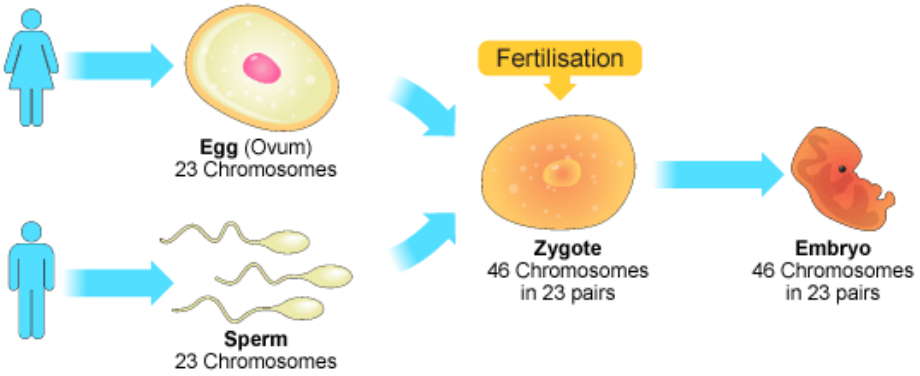
Sexual Reproduction

Organisms of a species that reproduce sexually are not identical therefore, they exhibit variation. Variation or differences in traits are caused by genetic factors (what genes you are born with) and environmental factors but only genetic variation can be passed onto the next generation by sexual reproduction.

Genetic material (DNA) carried in the egg & sperm (gametes) provide the inherited instructions for making offspring. The inheritance of this mixture of genetic material leads to variation in the offspring.

Sexual reproduction involves a mobile male gamete (sperm) fusing with a stationary female gamete (egg)

Both males and females only donate half of their chromosomes, one from each homologous pair, to form gametes through meiosis. (Gametes = egg or sperm). When the chromosomes from the egg and sperm rejoin to form a zygote with the total number of chromosomes fertilisation has occurred. Whether the zygote has the x or y chromosome from the male determines whether it is male (xy) or female (xx).



Gametes contain half the normal number of chromosomes and that fertilisation restores the normal number

Gametes are produced by the process of Meiosis – sperm in the males and eggs in the female. Meiosis randomly sorts one chromosome from each pair of chromosomes (remember there are 23 pairs or 46 individual chromosomes) contained in a cell and produces a gamete cell which will contain 23 single chromosomes.

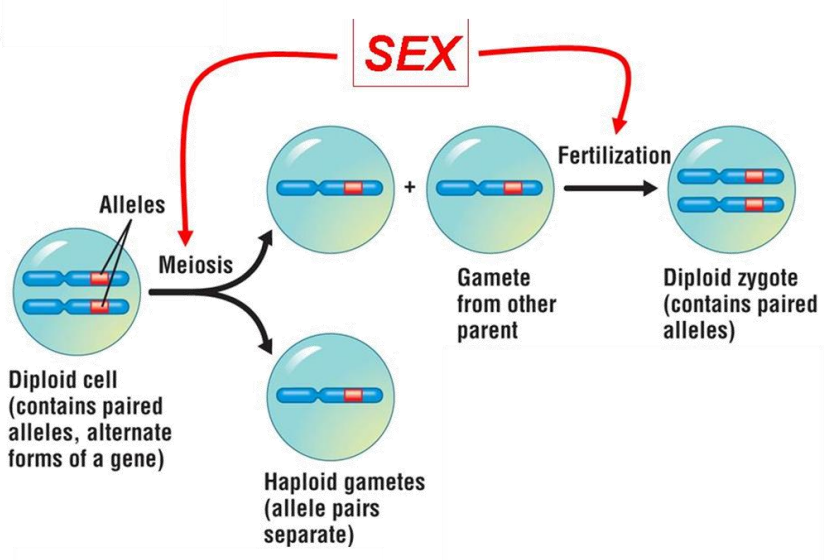
When the gametes combine during fertilisation, the 23 single chromosomes from each gamete re-join to form 46 or 23 pairs once more in the embryo cell.

Variation is due to genes being passed on from parents to offspring

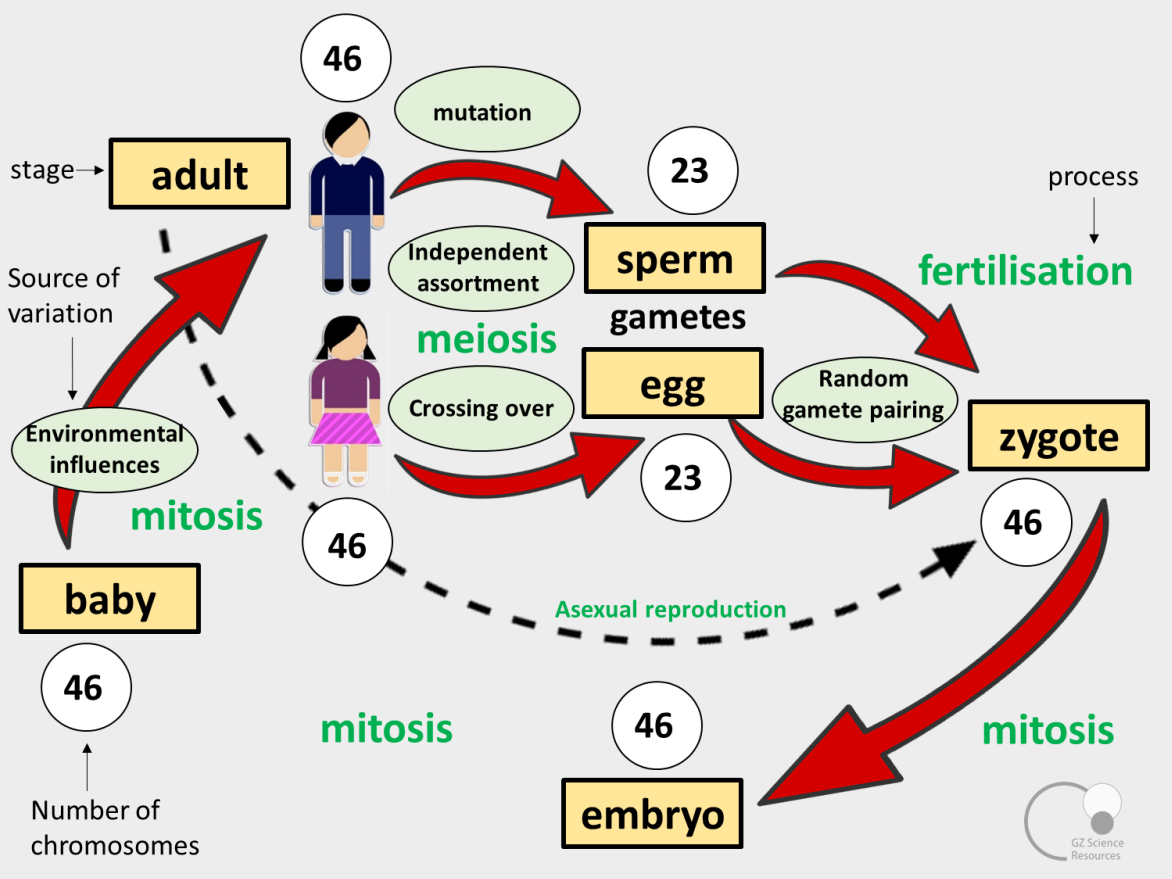
Genes are passed on from parents when the DNA in each parents gametes combine to form an embryo during fertilisation, which then develops into a baby.

Variation occurs when each parent's gametes are created – sperm in males and eggs in females – through a process of Meiosis.

Variation also occurs when a sperm cell fertilises a egg cell to produce a unique individual. Every single sperm and egg cell contain a different mix of chromosomes (although they of course must have one of each type) so each time an egg is fertilised by a sperm cell a different combination will be produced.



Variation Summary



Causes of Variation Summary

Gametes are sex cells (sperm and egg) which are formed in the testes and ovaries. During gamete formation (meiosis), the homologous chromosomes are halved and the gamete will inherit one of each pair of chromosomes. Which chromosome is passed on is random due to the process of independent assortment. When the pairs of homologous chromosomes are together during meiosis, they may swap pieces. This is called crossing over and results in more variation between each chromosome.

During fertilisation, the gametes combine and the resulting offspring will have two alleles – they may inherit two alleles the same, homozygous, and show that characteristic or they may inherit one of each allele, heterozygous in which case they will show the dominant allele in their phenotype.

If Mutation occurs in a gamete then its effects will be inherited. Mutations are often harmful or fatal and are quickly removed from the gene pool. If a mutation is not harmful or if it is beneficial then a new source of variation is introduced to a species. Mutation is the only way new alleles can be added.

Comparing Asexual Reproduction and Sexual reproduction

Asexual reproduction occurs when only a single individual passes on all its genes to the offspring. The offspring are genetically identical to the parent. Sexual reproduction occurs when two parents create offspring and pass only half their genes to the offspring. The offspring half a different/unique set of genes.

Advantages for asexual reproduction are that only one parent is needed and identical offspring are adapted to same environment as parent. An advantage of Sexual Reproduction is that variation can increase survival chances of a species if the environment changes.

Summary of Advantages and disadvantages of Sexual Reproduction

Advantages	Disadvantages
Variation in offspring means that some will be better suited to changing conditions, and so will survive better.	Need two parents that are able to reproduce
Mates can be selected to pass on desirable traits to the offspring.	If conditions are stable it could introduce variation, which may be counterproductive.
Humans can selectively breed traits in other species for their advantage. For example different rose types.	Involves energy in producing reproductive structures or phenotypes to attract mates
	If pollination is unsuccessful, then no seeds are produced – i.e. a waste of energy and time, as no genetic material will be passed on to future generations
	Time consuming compared to asexual reproduction (takes time to produce reproductive structures, attract pollinators etc.)

Why is variation so important for a species survival?

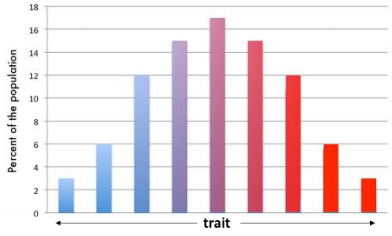
Traits in a species such as structural adaptations and behaviour are controlled by genes. These traits are also called the phenotype. Species that reproduce sexually show variation in the phenotype of individuals.

Variation in a species increases the chance of survival of a species if there is a change in the environmental pressures. Environmental pressures can include drought and lack of food or water, disease, flooding and sudden climate change. If there are some individuals with a phenotype (controlled by alleles) that are better suited to survive in the changed environment then they may be able to reproduce and past their alleles onto the next generation ensuring survival of the species. Without variation in a species, any sudden environmental change can mean that no individual has a phenotype that allows it to survive, causing the species to become extinct.

Variation in the coat length and thickness of a tiger have allowed it to survive in many different types of environment ranging from snow covered Siberian forest to tropical Malaysian jungle. From one original tiger species with variation, 10 subspecies have evolved.

During a "typical" season in any environment, an average phenotype for any particular trait is most likely to be best adapted to the environment and therefore the organism having it will have the best chance for survival. Those "average" phenotypes are likely to make up the largest percent of the population.

In an "atypical" season that may be drier/wetter, or hotter/colder, then individuals with more extreme versions of a phenotype (alleles) may have the advantage of survival. If the conditions have a very large change then sometimes only those with extreme phenotypes survive. Permanent shifts in the frequency of alleles to either end is called evolution.



Why is variation so important for a species survival? – Moths

A species of moth has two phenotypes, light and dark. Birds eat both light and dark moths. Explain how the two phenotypes of the species of moth help the population to survive if the environment changes and all the trees on which the moths live become darker.

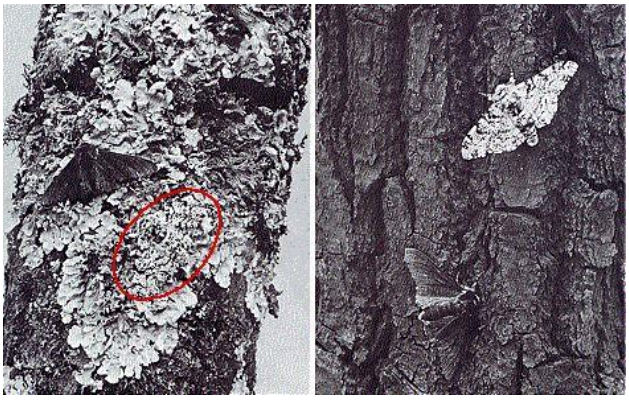
Explanation – colour

White bodied moths are more visible on a dark background and easily preyed upon. Dark coloured moths are more visible against a light / lichen background.

Explanation – environment

Individuals that are best suited to an environment will survive to reproduce and pass on their genes to future generations. This will lead to increase in numbers of the moth with an advantageous phenotype.

If the environment changes, e.g. trees become darker, those individuals with dark bodies will have the beneficial characteristic and pass this onto their offspring, while the light coloured moths will stand out and be preyed upon, therefore reducing in number. As a result the phenotypic ratio will change to more dark than light over time.



Why is variation so important for a species survival? – Giraffe case study

The length of a giraffe's neck, a phenotype, is controlled by genes. There is continuous variation of the neck length within a population. A longer neck will help giraffes reach leaves higher in the tree but makes it more difficult for the animal to drink and for blood to circulate to the head compared to a shorter neck giraffe. During 'typical' years when there is sufficient food an average length, neck will be favoured.

In a year where there is a drought, and a shortage of food, the giraffes with a longer neck phenotype are more able to reach higher into the trees for food than the shorter necked giraffes can. The extra food that the longer necked giraffes can eat may mean their survival and reproductive rate is higher than shorter necked giraffes and they pass their alleles onto the next generation and allow the species to survive.

If there was no variation in giraffe neck length, and no giraffe could reach higher than another could, then in a drought year, every giraffe would face equal opportunity of starving and the entire population of giraffes would be at risk of extinction.