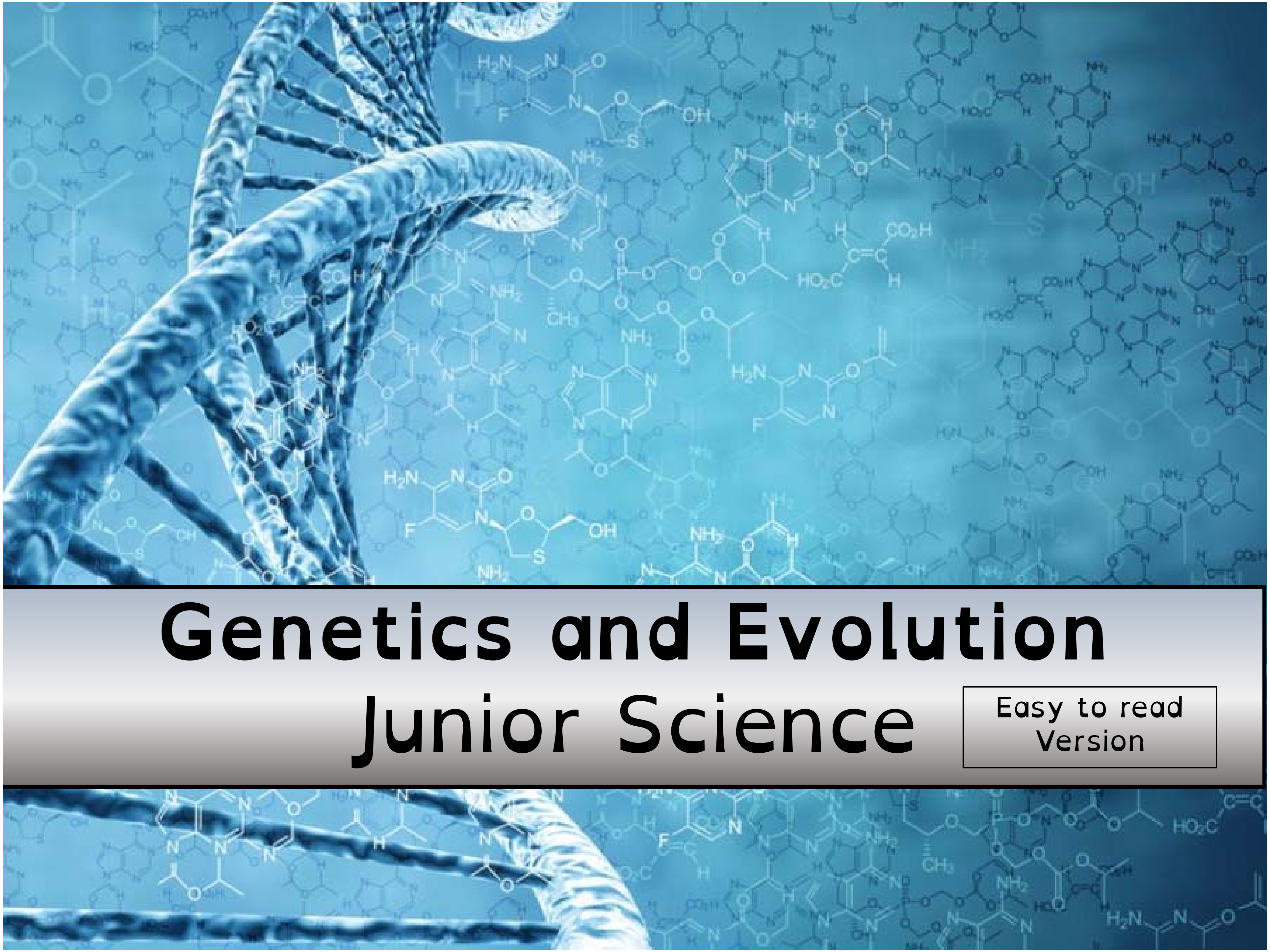


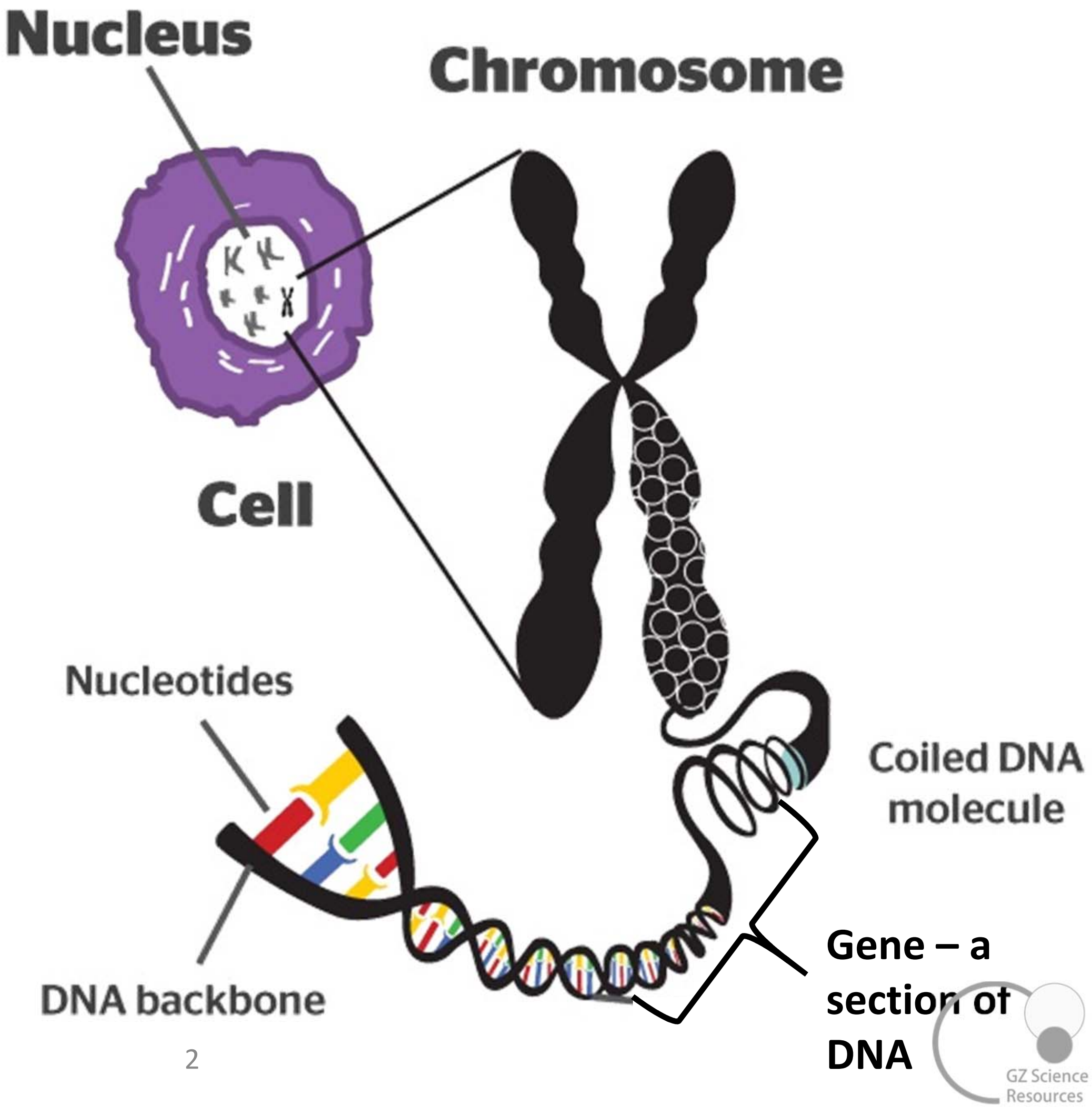
Genetics and Evolution

Junior Science

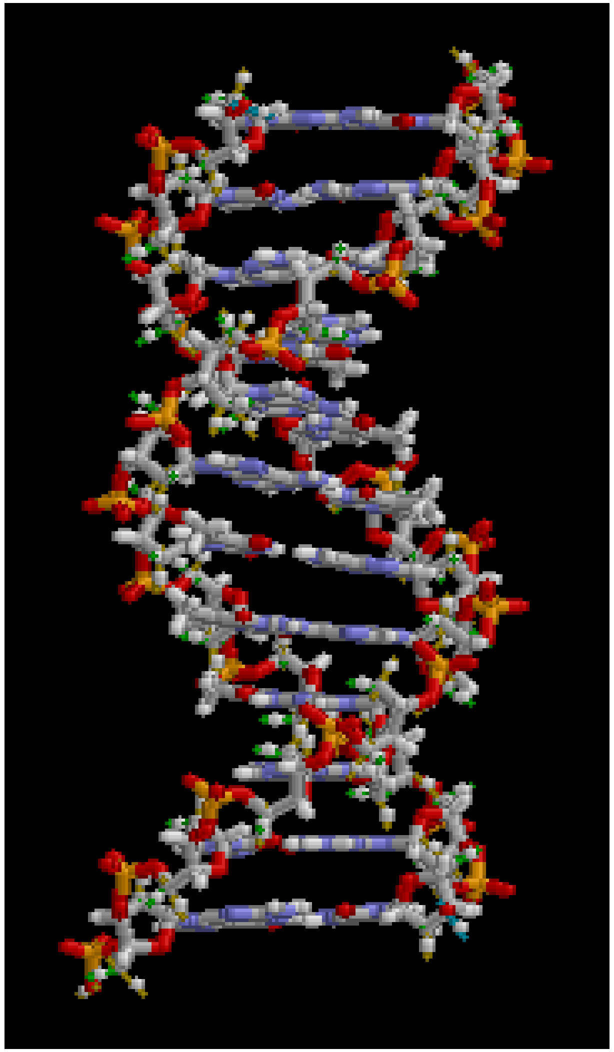
Easy to read Version

1a 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.**



1a DNA forms a Double Helix shape



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.

1b

A nucleotide is one unit of DNA

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

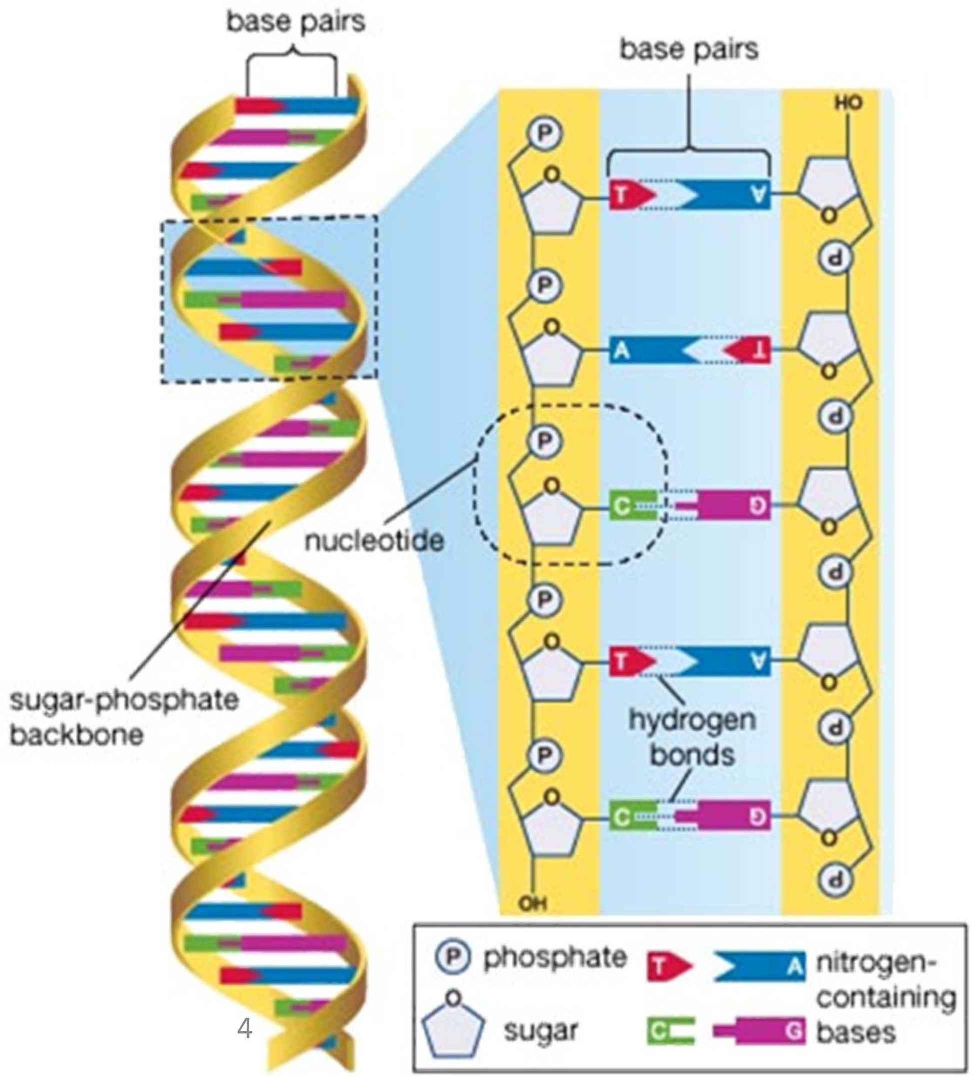
There are 4 bases

A – Adenine

C – Cytosine

G - Guanine

T – Thymine

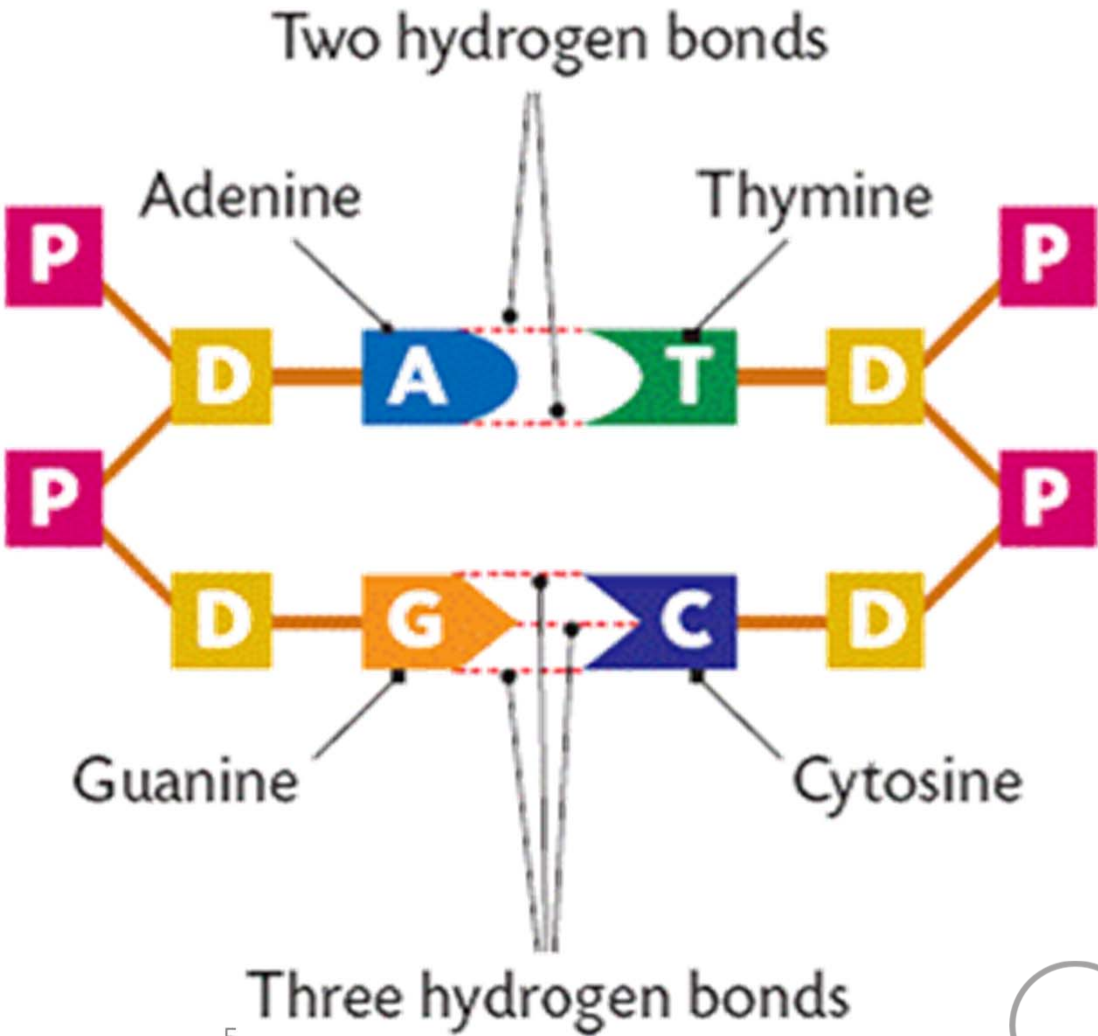


1c Bases form pairs with each other

The RNA and DNA nucleotides join together to form a long ladder which spirals into a double helix.

G bonds with C

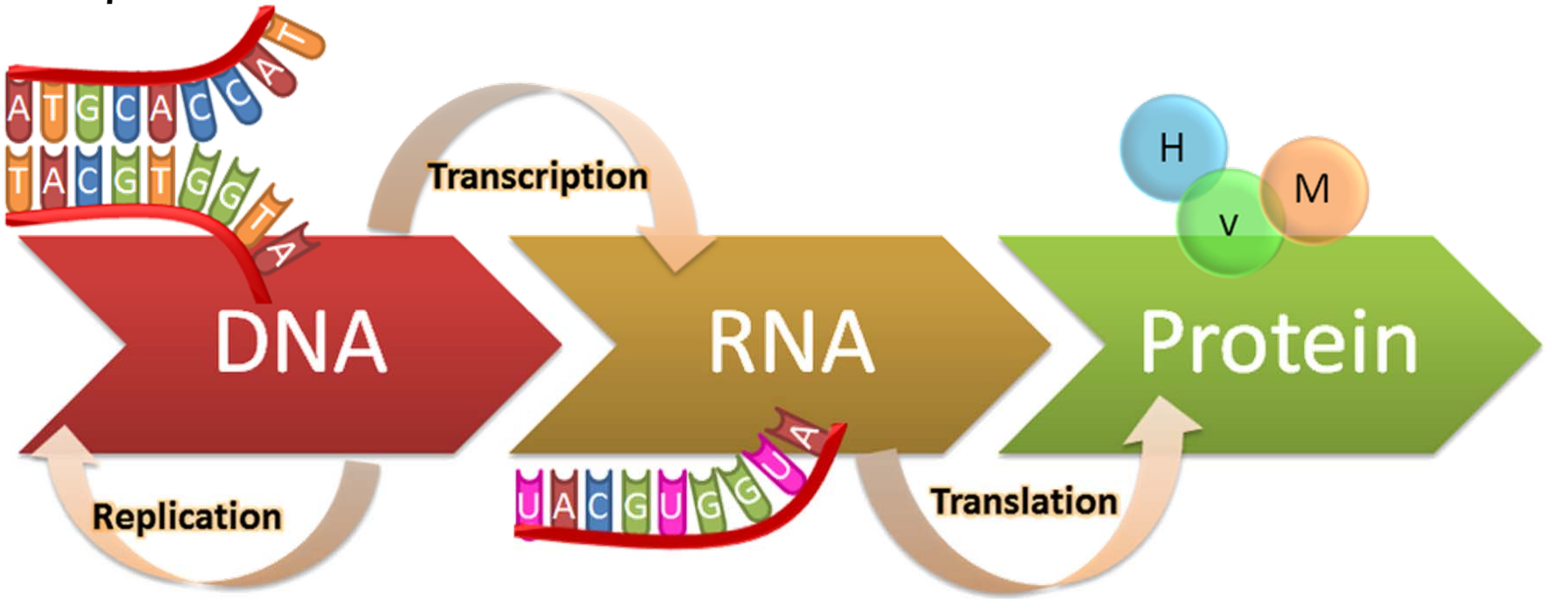
A bonds with T



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

1d

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.

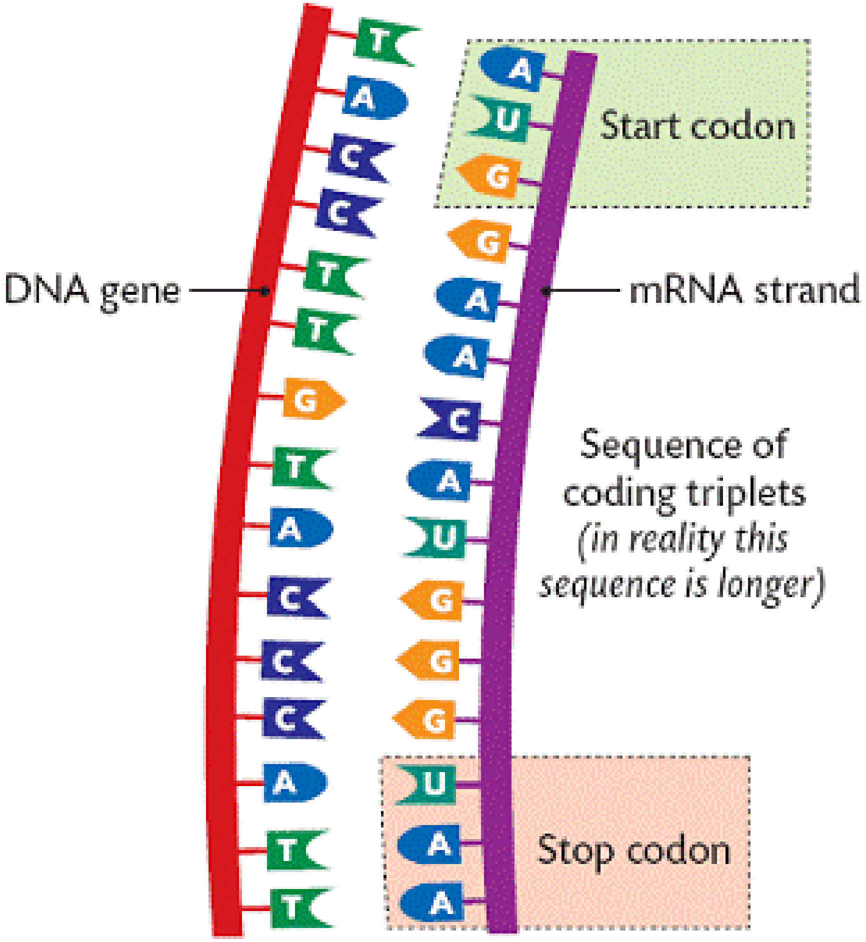


A **single stranded copy** of DNA from a gene is called **RNA.** (Transcription).The RNA moves out of the nucleus into ribosomes and the codons code for different amino acids which link together to form a protein molecule. (Translation)

1d

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

Extra for experts



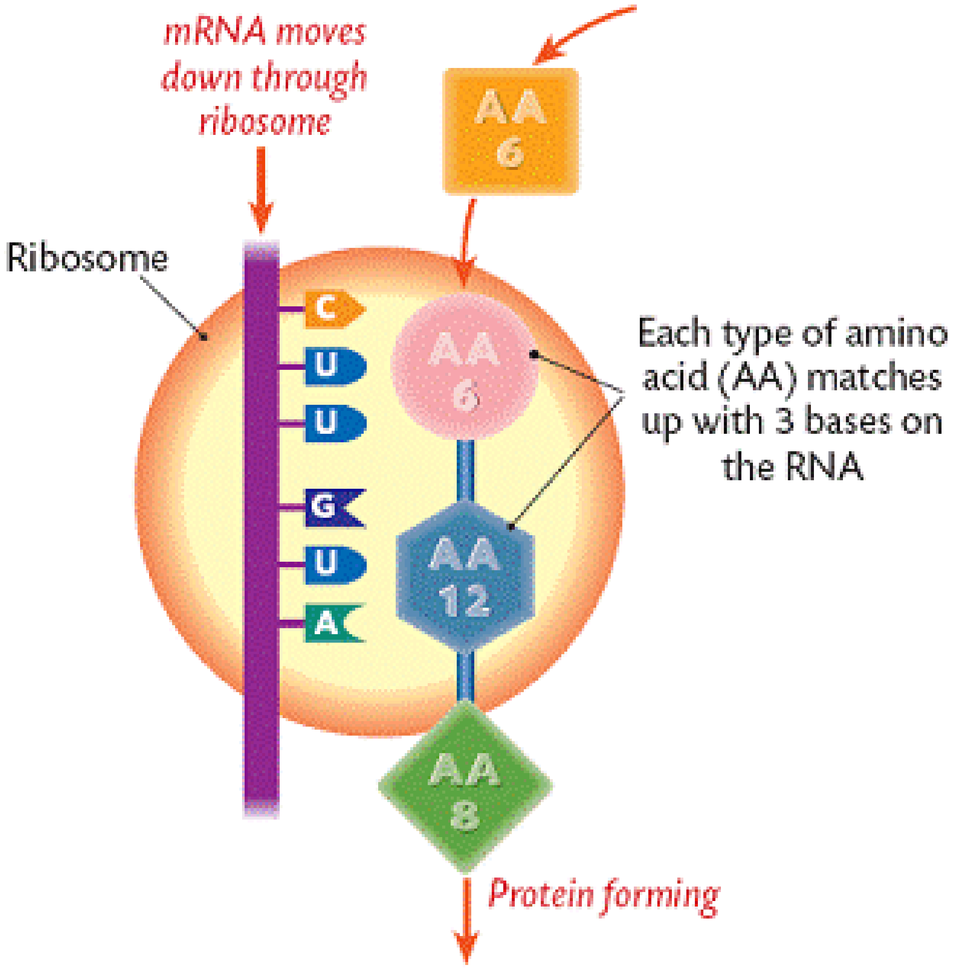
A **gene** is a code for one protein. When the cell requires a type of protein a copy of the particular gene is taken. **mRNA** (messenger RNA) is the name of the "photocopy" and it consists of a single strand of matching bases of the gene.

The mRNA then moves out of the nucleus and into a **ribosome** where the protein manufacture starts.

1d

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

Extra for experts

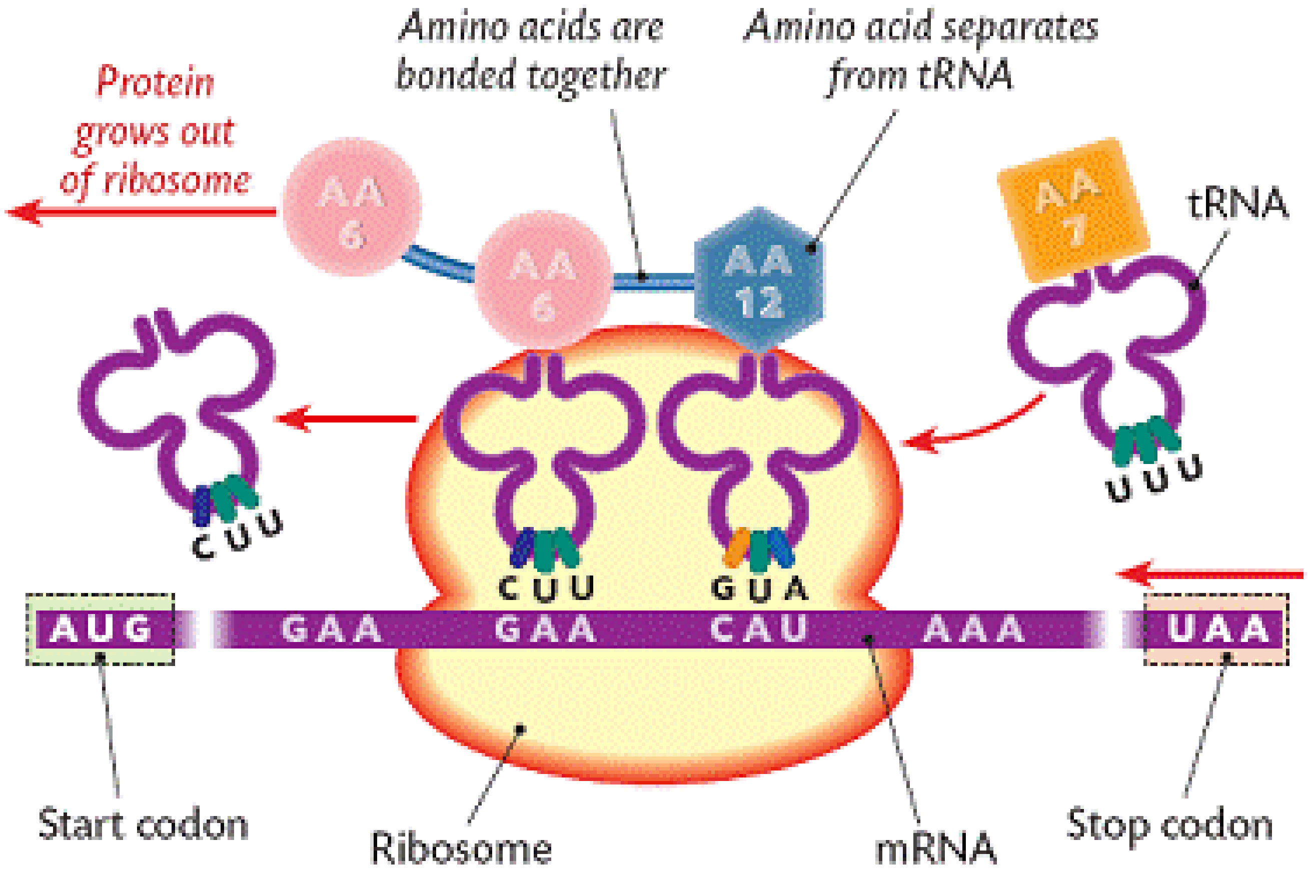


The mRNA moves through the ribosome as if it was on a conveyer belt. Each set of three bases called a **codon** codes for a particular type of amino acid to join to it. As each new amino acid is added it bond to the one beside it. This process continues until it reaches the end of the gene.

1d Genes are 'coded instructions' for making proteins and that DNA is the chemical which stores the coded instructions

Extra for experts

Special molecules called **tRNA** (transport RNA) bring along the appropriate **amino acid.** There is one type of tRNA for each variety of codon. Once the chain is complete it is then folded up into particular shapes and becomes the protein.



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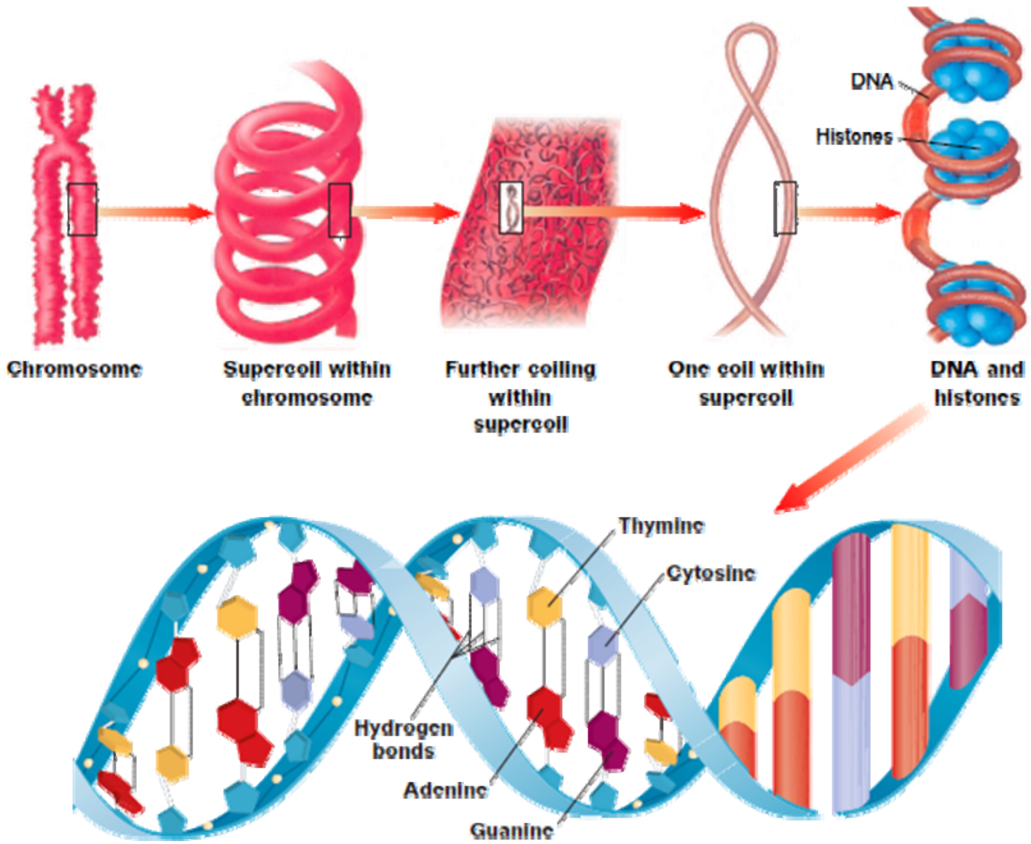
1d

Genes are ‘coded instructions’ for making proteins and that DNA is the chemical which stores the coded instructions



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.

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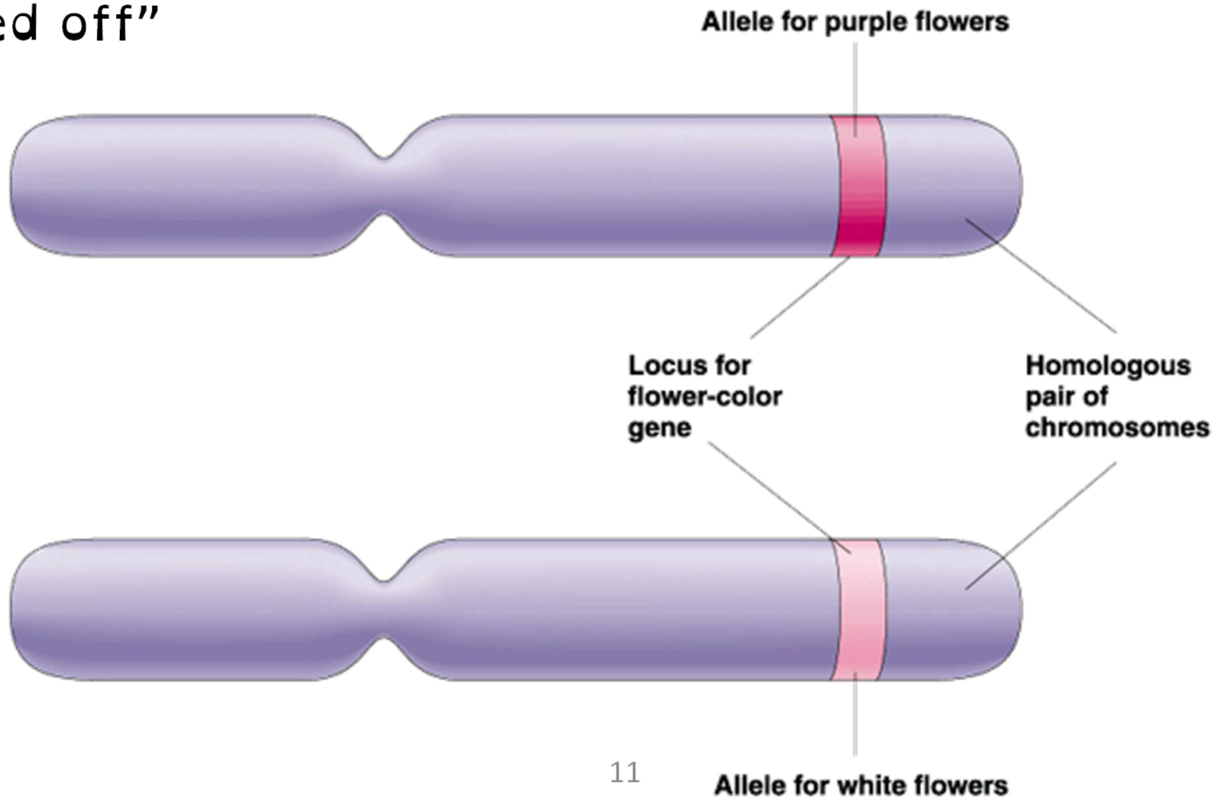
1e alleles

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 used the body only needs to use one of the alleles and the other allele is "switched off"



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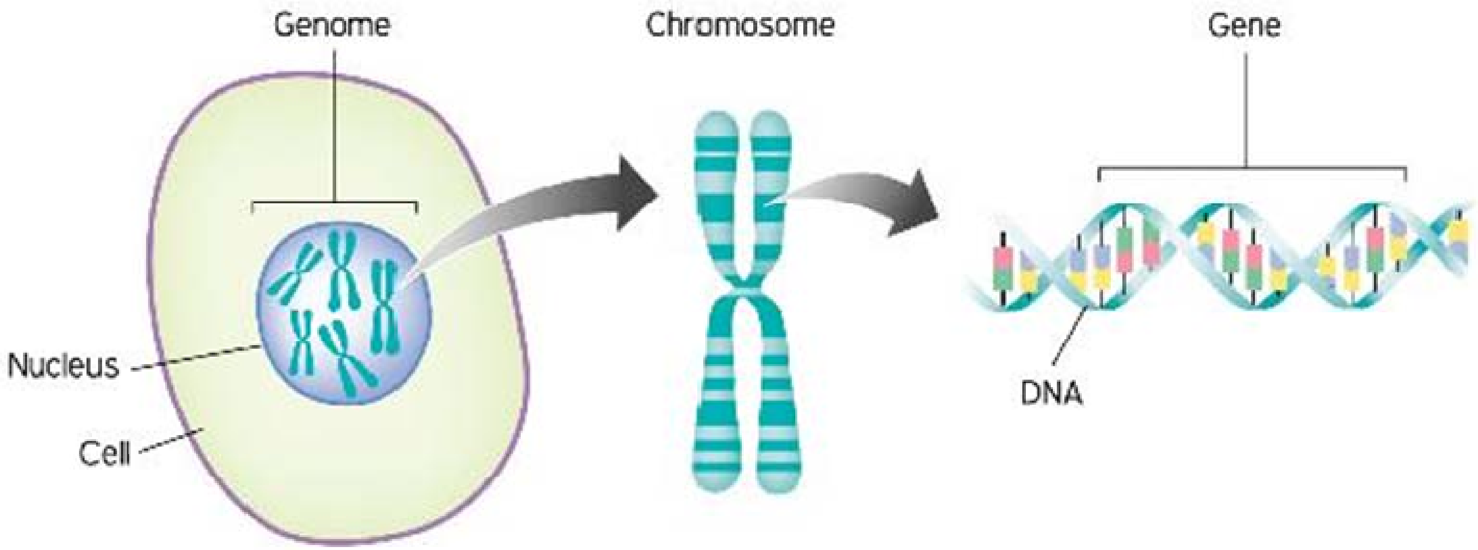
1e

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 use.



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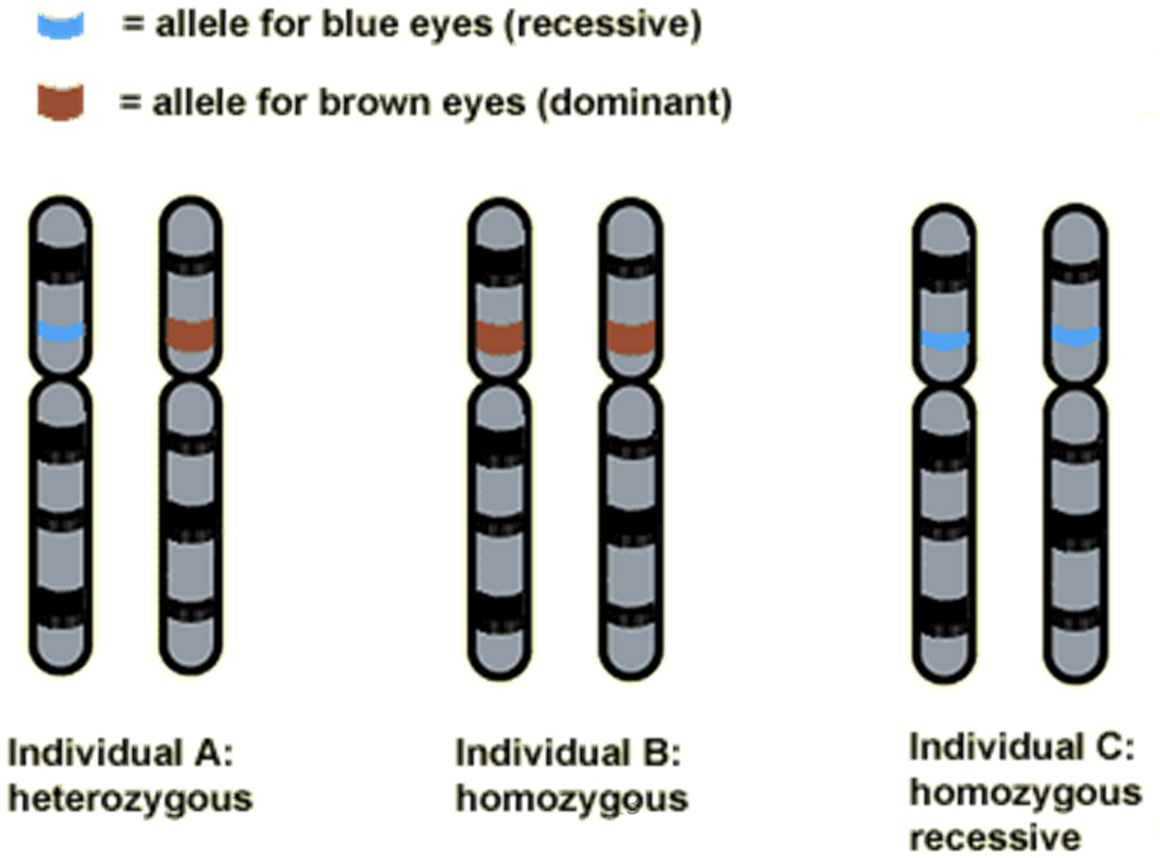
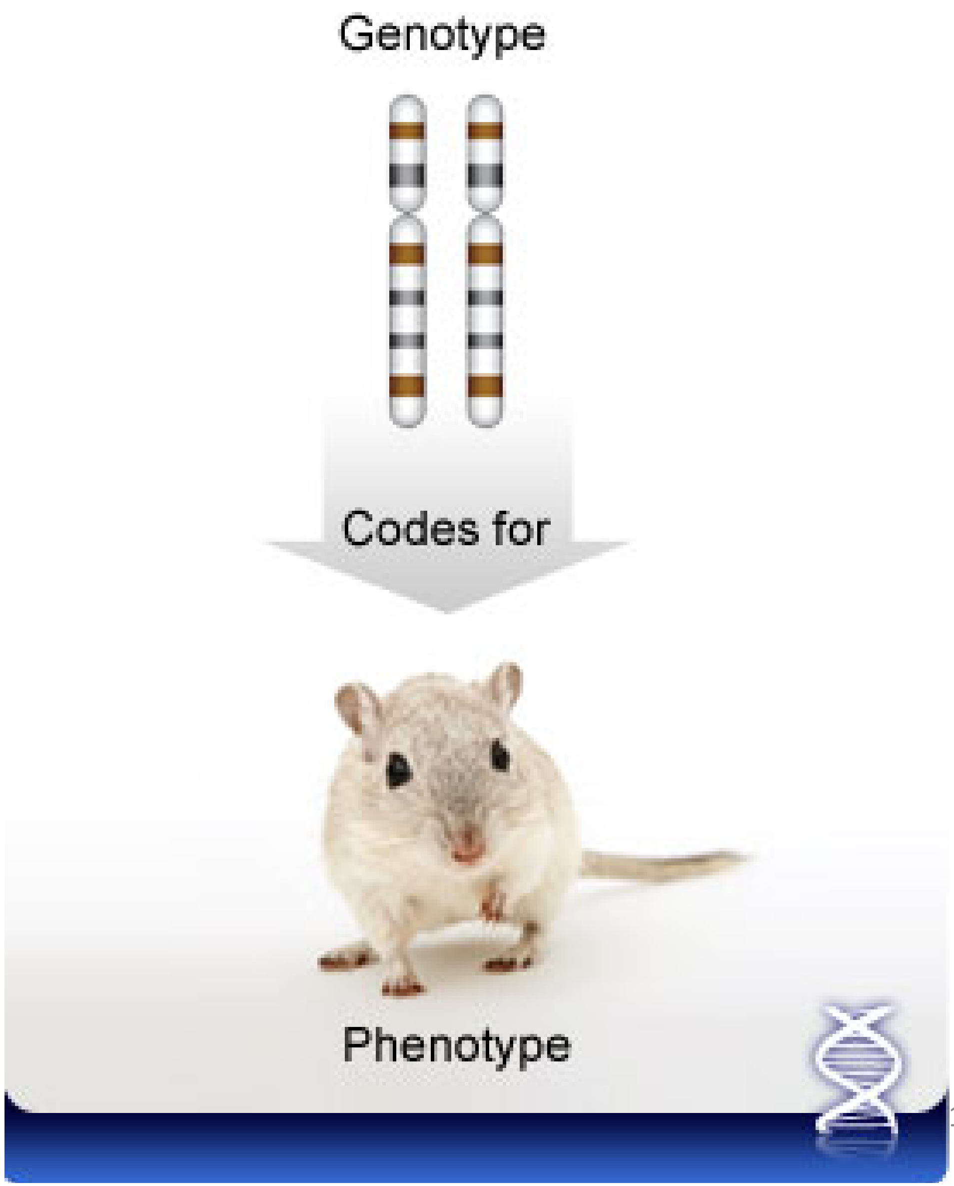
1f Dominant and recessive genes

The allele that the cell uses is called the **dominant** allele. The allele that the cell uses if the dominant allele is not present is called the **recessive** allele. When there are two of the same allele this is called **homozygous** and the cell could randomly use either. When there is 2 different alleles this is called **heterozygous** and the cell always uses the dominant allele. **Pure Breeding** is another term for homozygous.



1f

Phenotype and genotype



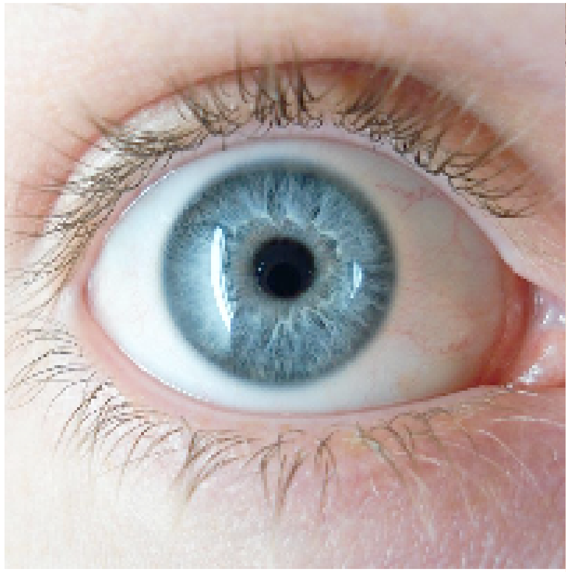
The **genotype** is the combination of alleles that an organism contains. For any particular trait they can be heterozygous (different) or homozygous (same). The genotype is given as a pair of letters – a capital letter for a dominant allele and a lower case letter for a recessive allele. i.e. AA, Aa or aa.

The **phenotype** is the physical trait that occurs because of the alleles.

1f Phenotype and 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 a one dominant allele is present in the genotype.

Phenotype= Blue Eyes



Genotype=bb

Recessive=b

Phenotype=Brown Eyes

Genotype = Bb or BB

Dominant =B

1f

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.

lop eared rabbit

straight eared rabbit

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

1f Putting it all together – Genetics Vocabulary

Extra for experts

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** (eg, eye colour) is called a **gene.**

The different versions of each gene are called **alleles**, and these show the different **variations** of each characteristic, eg 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).

2a

Gregor Mendel

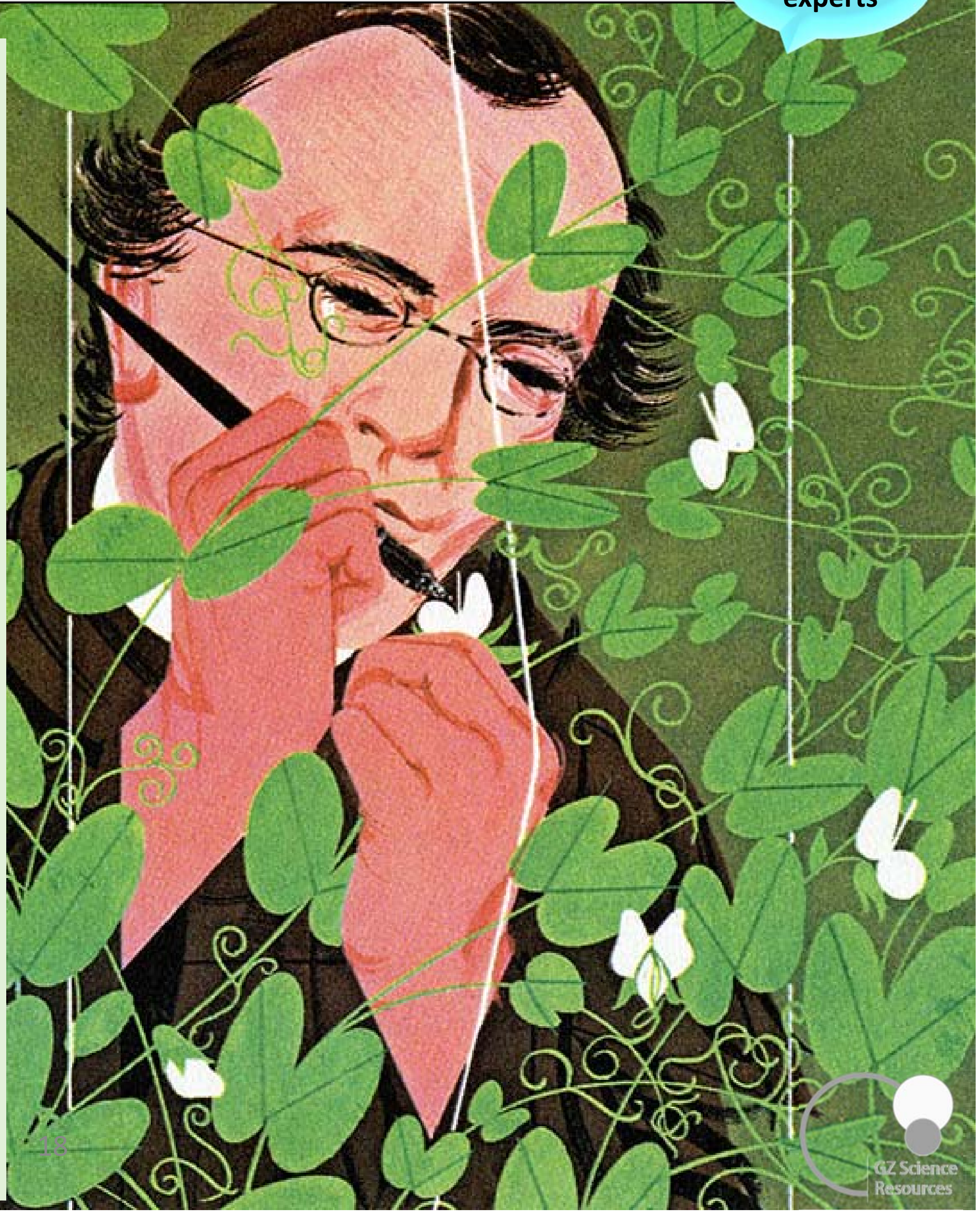
Extra for experts

Gregor Mendel was a German Friar who lived from 1822-1884. Mendel is called the “Father of Genetics” because through his work on over 10,000 pea plants he discovered the main laws of inheritance.

1) **The Law of Segregation**: Each inherited trait is created by a gene pair. Adult genes are randomly separated to the gametes and gametes contain only one gene of the pair. Offspring inherit one genetic allele from each parent when gametes combine in fertilization.

2) **The Law of Independent Assortment**: Genes for different traits are sorted separately from one another

3) **The Law of Dominance**: An organism with different alleles of a gene will use the allele that is dominant.



2b 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

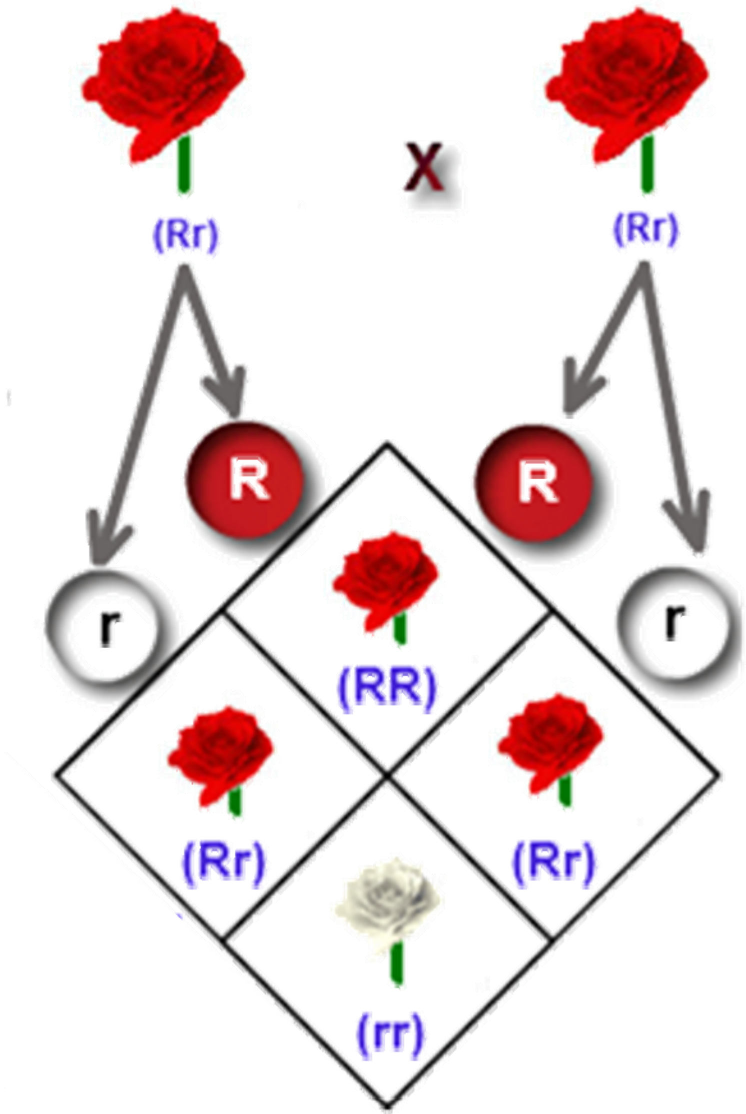
B is the dominate allele for Agouti colour.

b is the recessive allele for Black colour

Each adult gives one allele to each offspring.

2b 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).
Phenotype ratios are based on the numbers of each phenotype in the offspring.
Two heterozygous parents will produce a ratio of 3:1 – that is 3 dominant to 1 recessive phenotype in the offspring.



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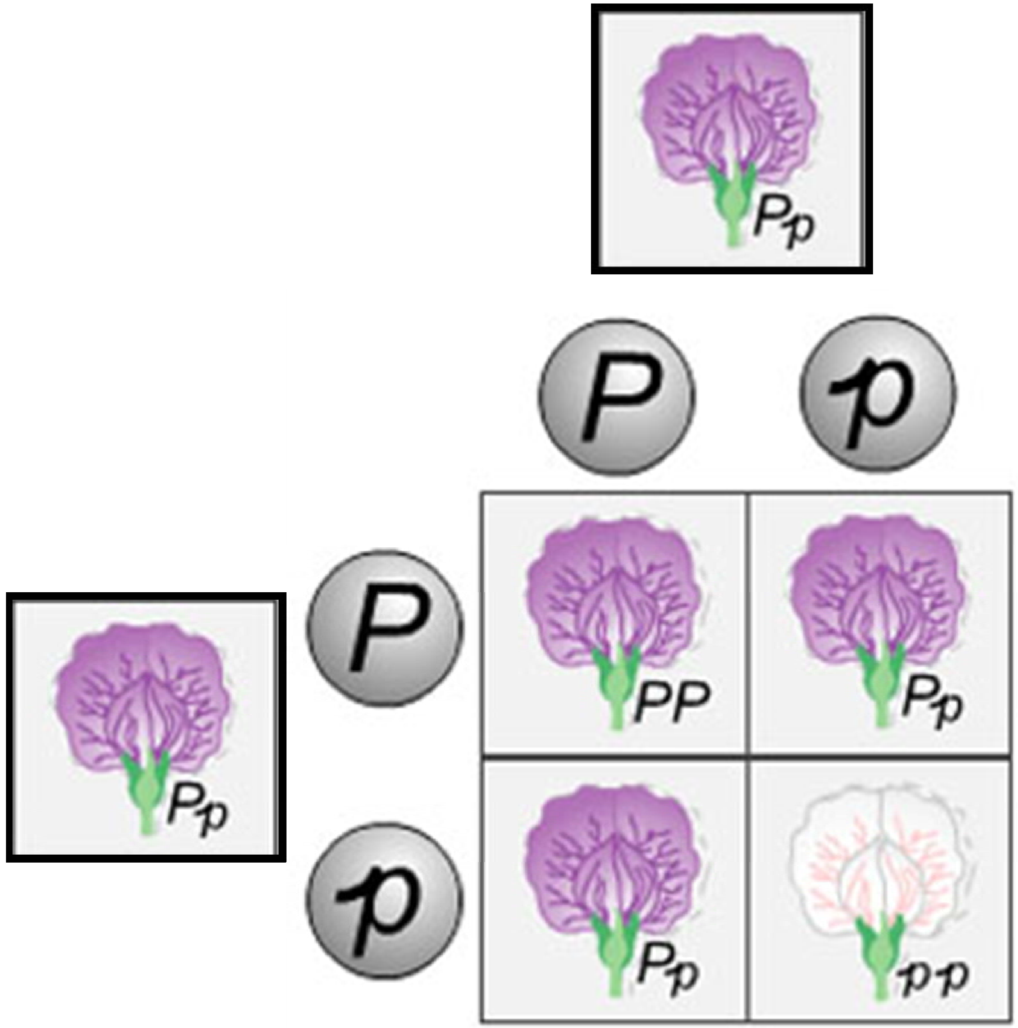
2b Using Punnett squares to predict offspring

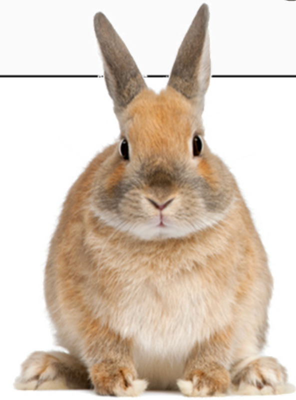
Genotype ratios when crossing two heterozygous parents are always 1:2:1. That is 1 dominant homozygous : 2 heterozygous : 1 homozygous recessive.
Genotype ratios when crossing one dominant homozygous and one recessive homozygous are always 0:4:0 with 100% of the offspring being heterozygous.



21

2c 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

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2c Calculating Phenotype and genotype ratios

1. **Determine** the **genotypes** of the parents or whatever is given in problem.
2. Set up your **Punnett square** as follows:

Male – BB genotype brown eyes - phenotype

Female – bb genotype blue eyes - phenotype

Genotypic ratio = 100% Bb

Phenotypic ratio = 100% Brown eyes

male

female

	B	B
b		
b		

3. **Fill in** the squares. This represents the possible combinations that could occur during fertilization.
4. **Write out** the possible **genotypic ratio** of the offspring.
5. **Using** the **genotypic** ratio determine the phenotypic ratio for the offspring.

2c Calculating Phenotype and genotype ratios

A heterozygous male, black eyed mouse is crossed with a red eyed, female mouse. Predict the possible offspring!

Male – Bb genotype
black eyes - phenotype

Female – bb genotype
red eyes - phenotype

Black must be dominant (B) as phenotype is black when mouse is heterozygous (has both B and b)

male

female	B	b
b		
b		

Genotypic ratio = 50% Bb 50% bb
Phenotypic ratio = 50% Black eyes 50% red eyes

2c Calculating Phenotype and genotype ratios

A heterozygous, smooth pea pod, plant is crossed with a wrinkled pea pod plant. *There are two alleles for pea pod, smooth and wrinkled.* Predict the offspring from this cross.

<u>heterozygous</u> Bb genotype
smooth - phenotype

<u>homozygous</u> bb genotype
wrinkled - phenotype

Smooth must be dominant (B) as phenotype is smooth when plant is heterozygous (has both B and b)

smooth

wrinkled	B	b
b		
b		

Genotypic ratio = 50% Bb   50% bb
Phenotypic ratio = 50% smooth   50% wrinkled

2c Calculating Phenotype and genotype ratios

Two heterozygous, smooth pea pod, plants are crossed.
There are two alleles for pea pods, smooth and wrinkled.
Predict the offspring from this cross.

<u>heterozygous</u> Bb genotype smooth - phenotype

Smooth must be dominant (B) as phenotype is smooth when plant is heterozygous (has both B and b)

smooth

wrinkled

	B	b
B		
b		

Genotypic ratio = 25% BB 50% Bb 25% bb
Phenotypic ratio = 75% smooth 25% wrinkled

2c Using Punnett squares to predict parents genotype

Extra for experts

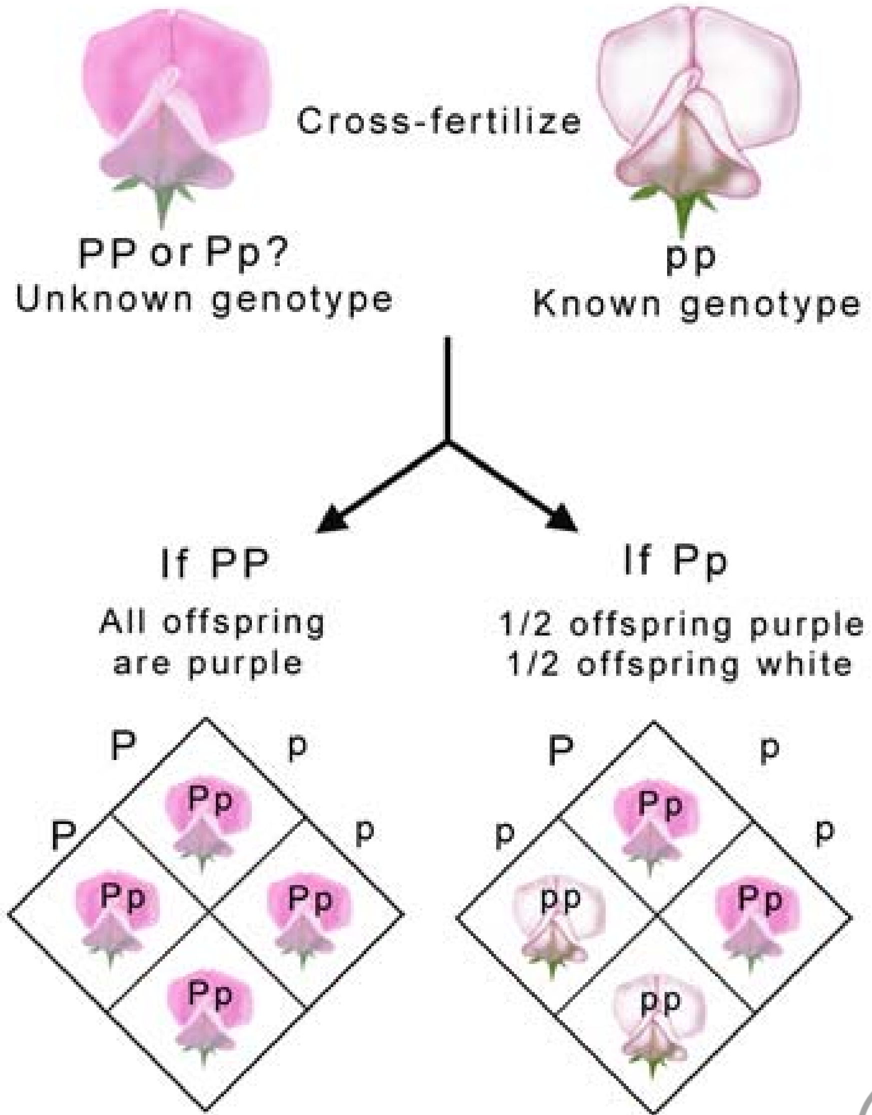
Parents genotypes can be predicted by the phenotype of the offspring. If 100% of the offspring show the dominant phenotype then at least one of the parents must be homozygous dominant.

If any of the offspring show the recessive phenotype then each parent must contain at least 1 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.

2c Pure breeding and test crosses

Extra for experts

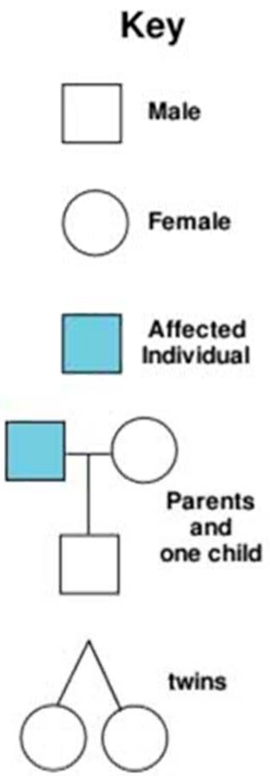
An individual that is **pure breeding** has a homozygous (two of each allele) genotype. The pure breeding recessive homozygous can be seen by its phenotype – it will show the recessive phenotype. The pure breeding dominant homozygous has the same phenotype as a heterozygous individual however. The pure breeding 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.

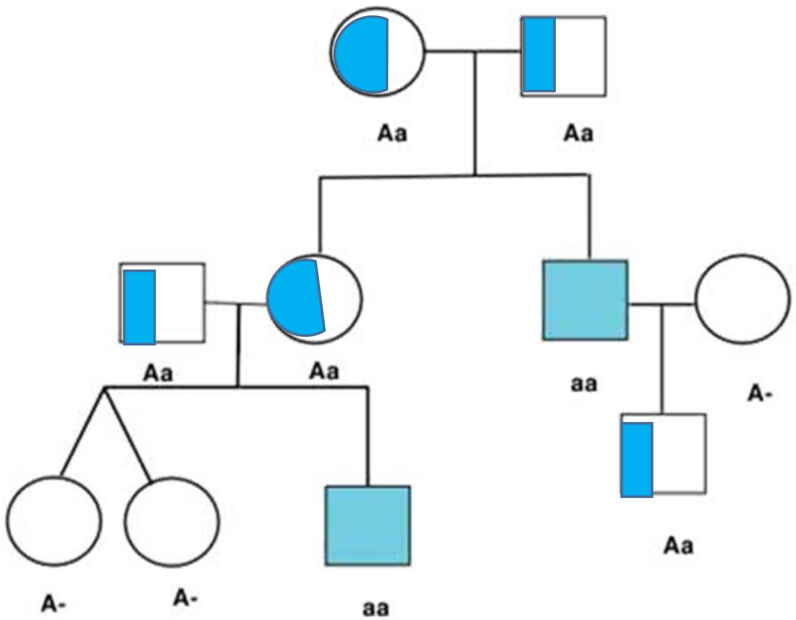


Using Pedigree charts to predict offspring

Extra for experts

A pedigree chart is a diagram that shows **inheritance** patterns of a certain allele. 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. It if is half-shaded, then they are heterozygous but do not have the phenotype. If they are not shaded at all, they don't have the allele. Pedigrees are good for showing the patterns of a recessive or dominant gene.





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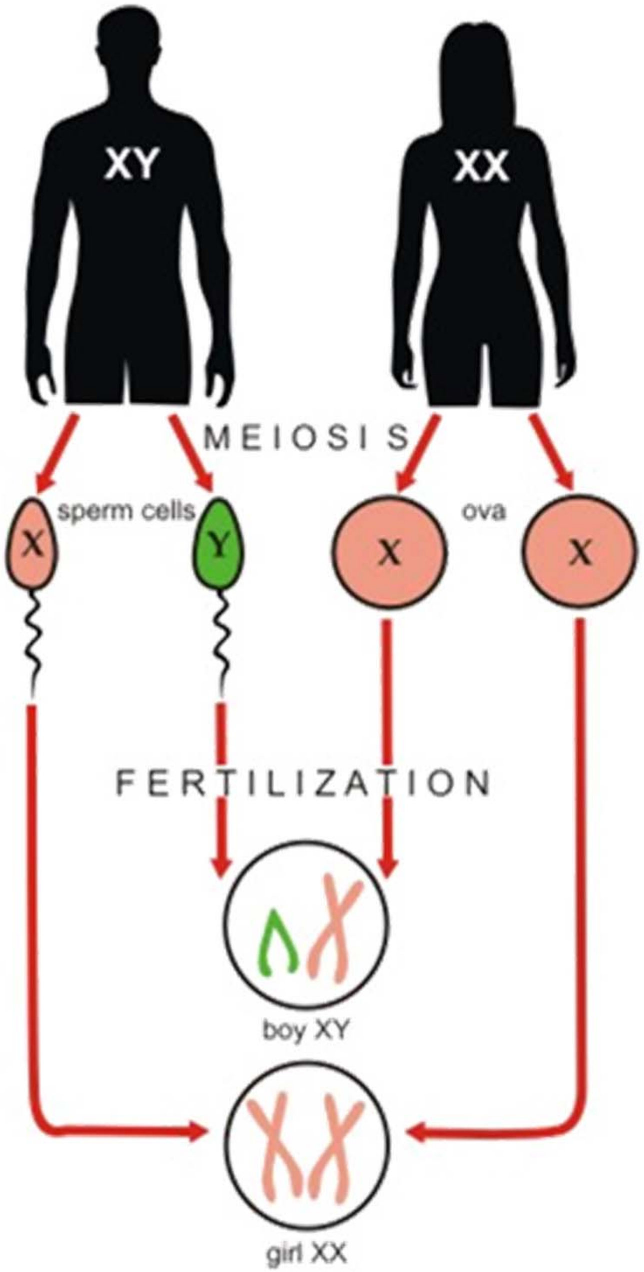
2d

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 a x chromosome. The male has a 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.



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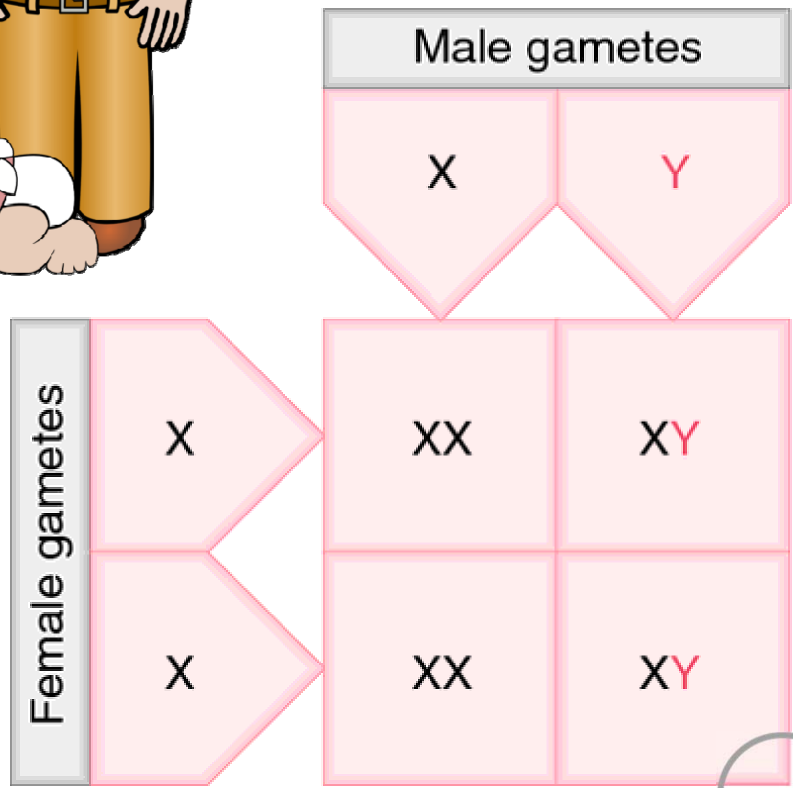
2d Sex determination

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 fertilisations.



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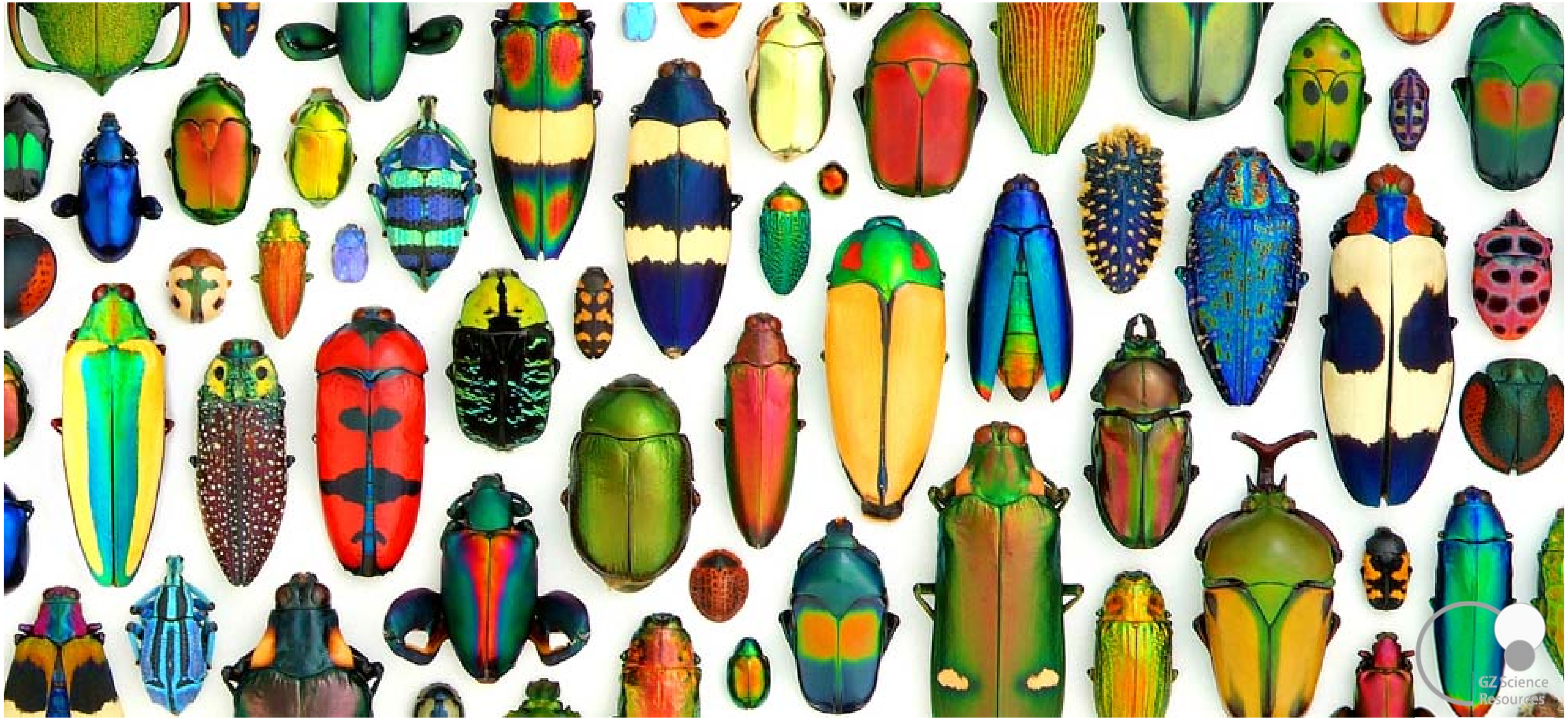
3a

Variation

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



3a

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.

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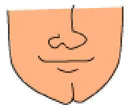
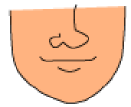
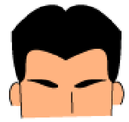
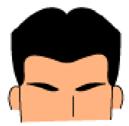
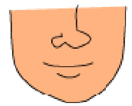
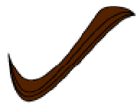
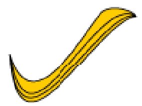
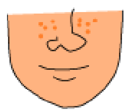
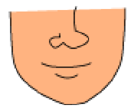
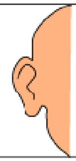
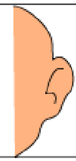
3a Inherited and Environmental Variation

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.
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.

Examples of inherited Traits

Dominant Gene		Recessive Gene	
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	

3a Environmental Variation – Hydrangea Case study

Extra for experts

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.

3b Continuous and discontinuous variation

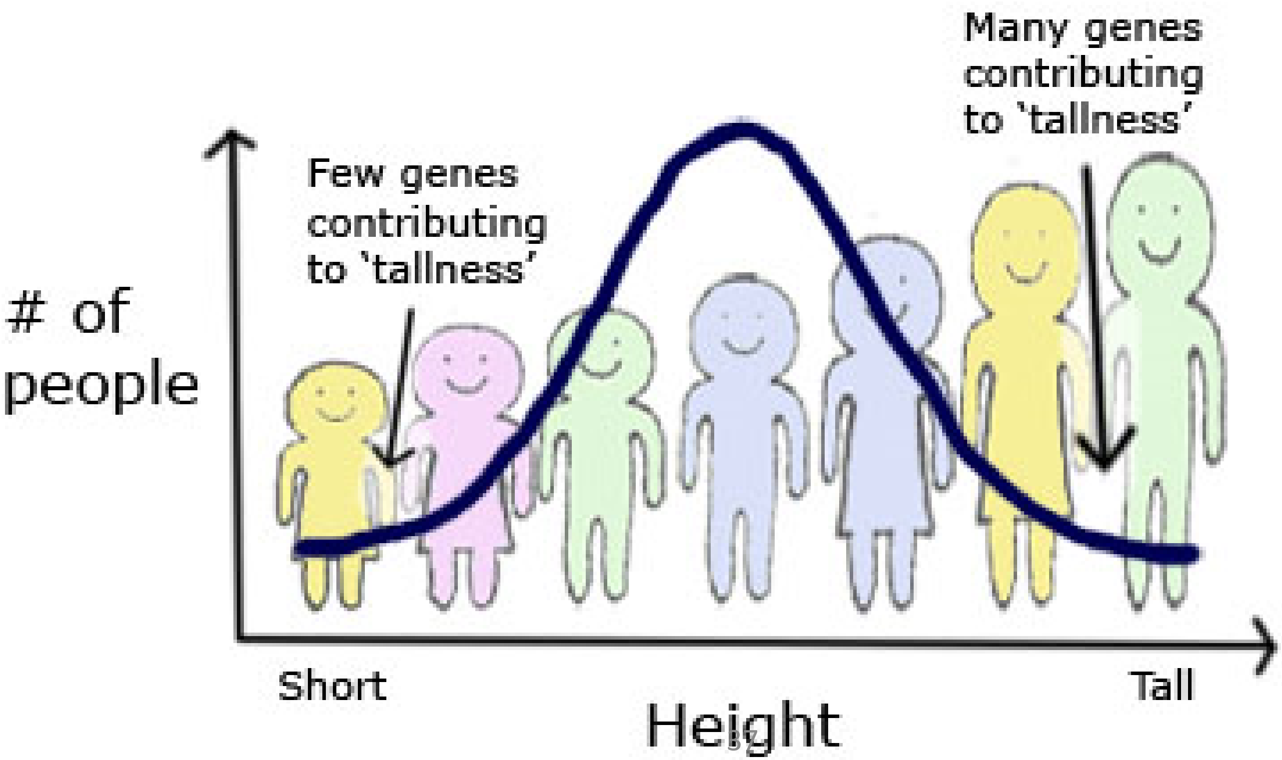
Variation of a trait in an individual can be **continuous** such as tallness where height can be either very tall or very short as well as any height in between. Offspring will most often show height half way between the two parents as alleles inherited from both parents have a combined effect.

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

Human Traits

Extra for experts

Traits that cause continuous variation are created by a group of genes. When a random group 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.
In the example below, many more people tend to be of average height compared to being very short or very tall.



4a

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

There are **three main processes** that cause variation between parents and their offspring. Each of these processes either introduces new alleles into the offspring or mixes up the combination of alleles received from the parents to ensure each individual offspring has a different assortment of alleles while still receiving the complete set of genes required.

Sexual reproduction

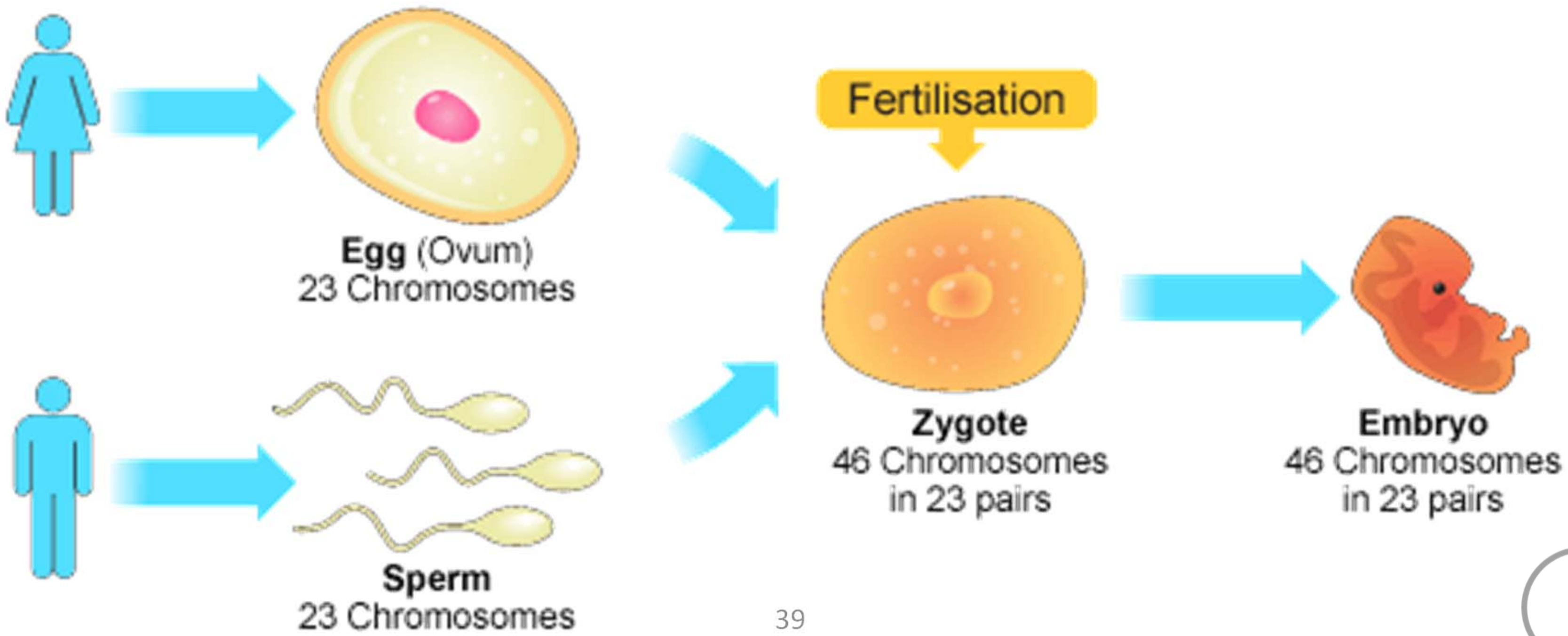
Meiosis

Mutation

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

4b

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).



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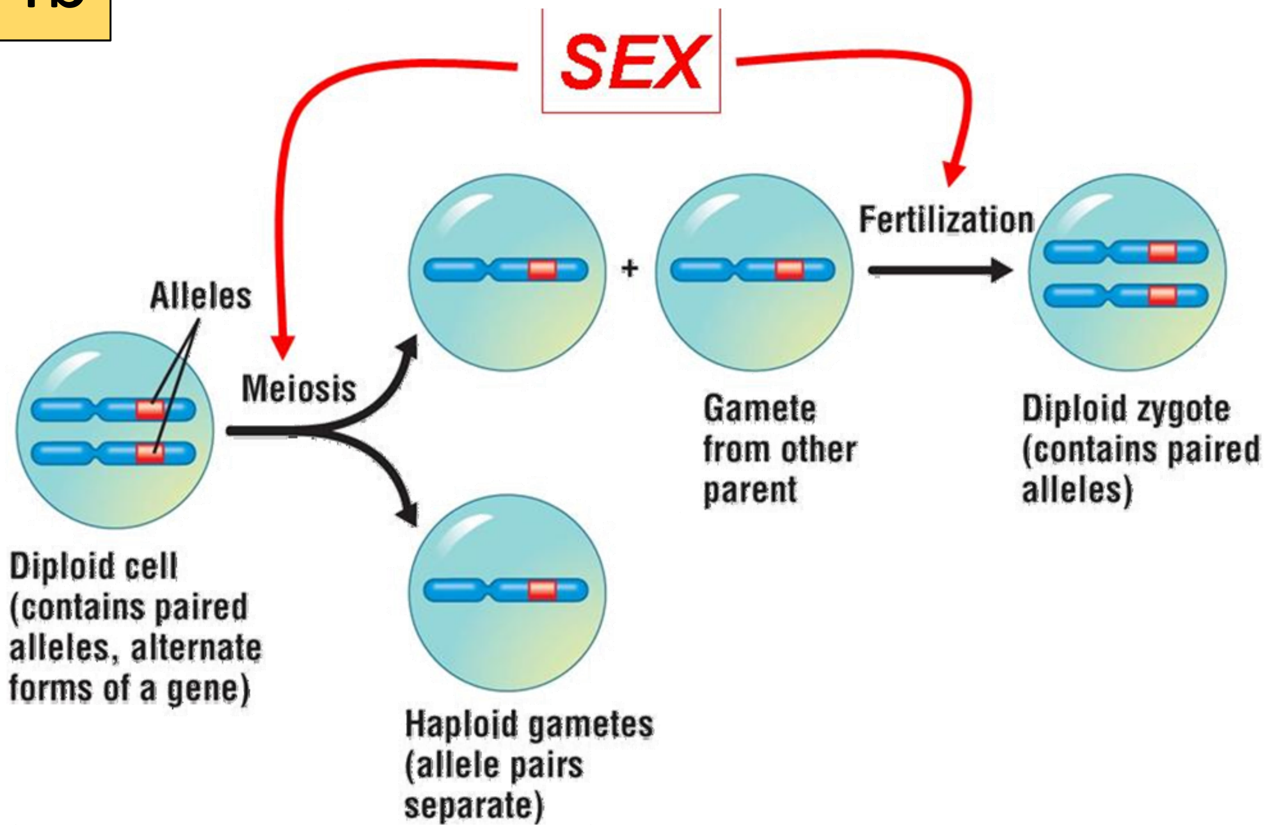
4b Understand that variation is due to genes being passed on from parents to offspring during sexual reproduction



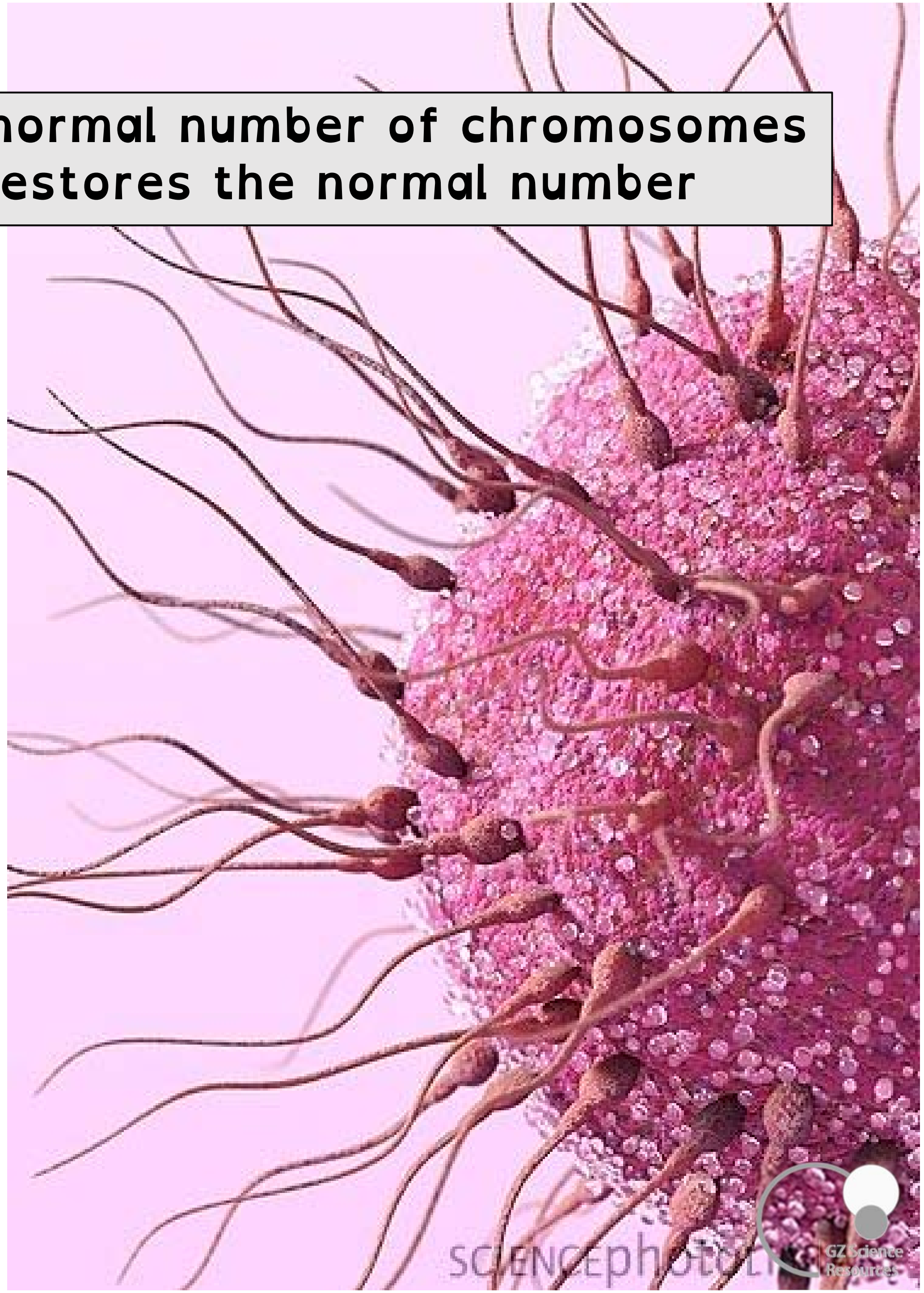
Genes are passed on from parents when the DNA in each parents gametes combine to form an embryo during fertilisation which then develops into a baby.
Variation occurs when each parents gametes are created – sperm in males and eggs in females – through a process of **Meiosis.**

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.

4c

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.

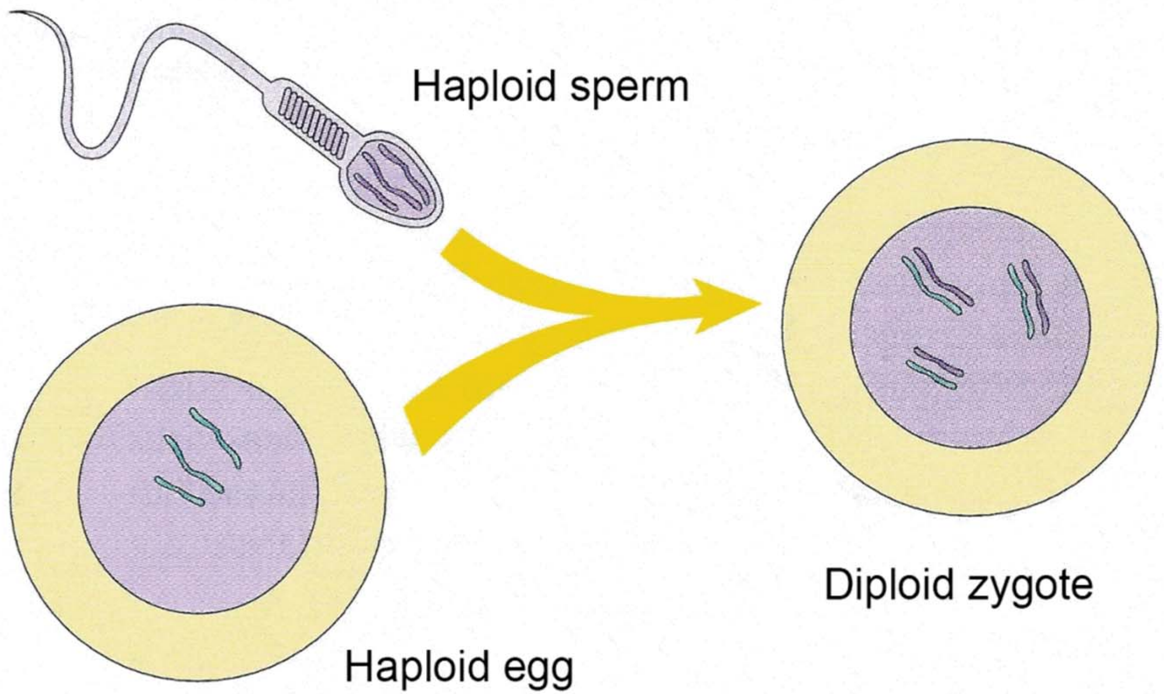


4c

Haploid and Diploid

Extra for experts

Gametes contain only one set of chromosomes and are known as **haploid** (or half). All other cells in an organism contain the usual two sets of chromosomes inherited from both parents and are known as **diploid** (2 or double).

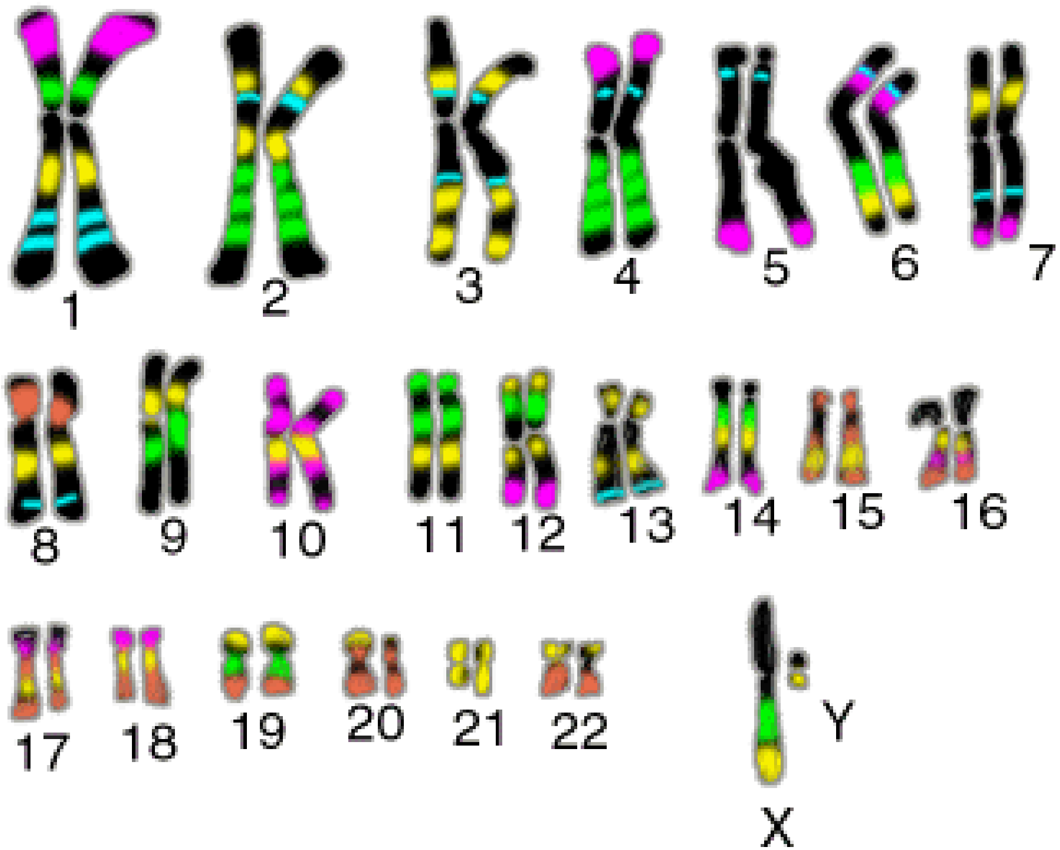


Some species such as bacteria, fungi and some plants consist entirely of haploid cells. These species undergo asexual reproduction to produce identical offspring so the chromosome number remains the same rather than doubled up like during the fertilisation of sexually reproducing species.

4c

Chromosomes come in pairs

Chromosomes come in pairs. One pair is the sex chromosomes – XX in females and XY in males. 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.



4c

Chromosome numbers of other species

Extra for experts

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.

26

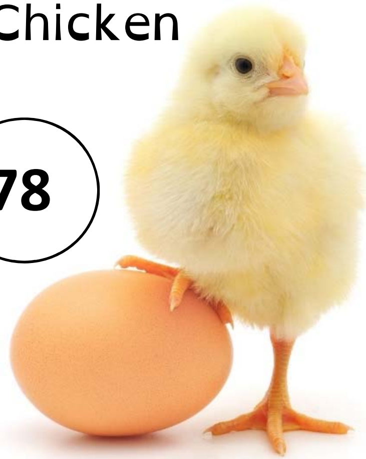
Frog

Pea

14

Chicken

78



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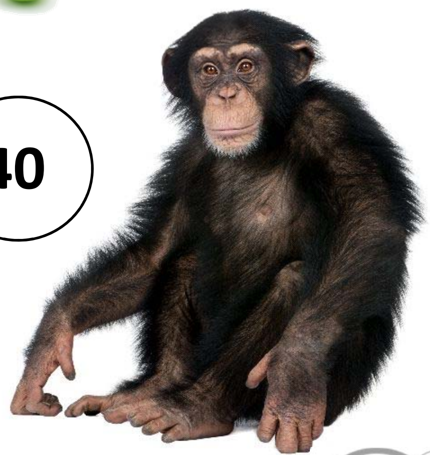
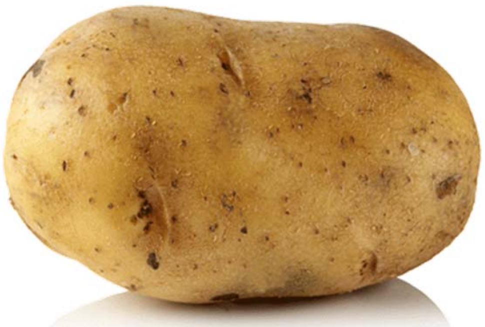


Chimpanzee

Potato



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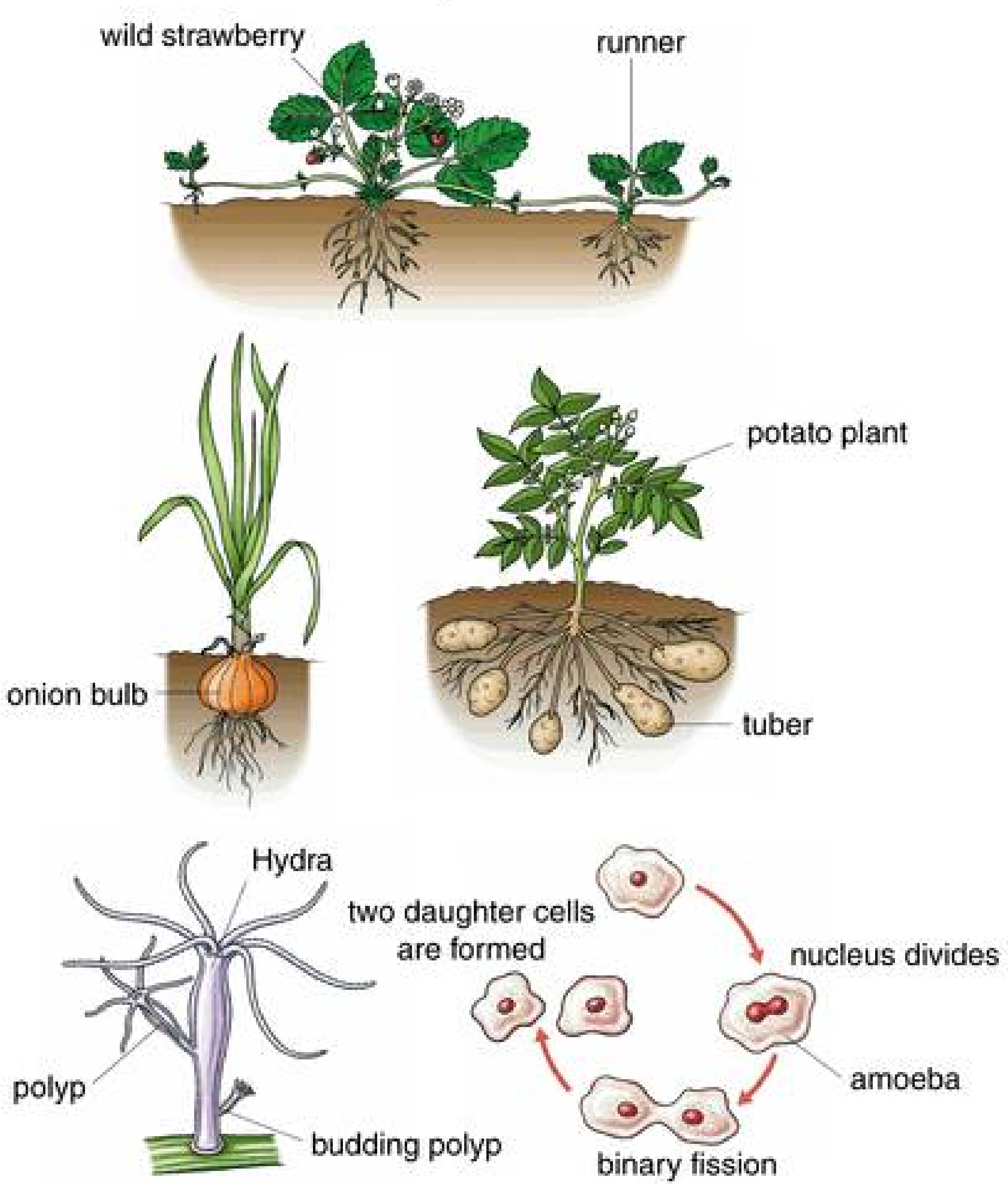
4d Asexual reproduction produces identical offspring



Some organisms, more commonly bacteria and plants but also some animals, reproduce asexually. This type of reproduction does not involve the manufacture of sex cells (gametes) from two parents. Every new organism produced by asexual reproduction is genetically identical to the parent – a **clone.** The advantages are that there is no need to search for a mate. Asexual reproduction can therefore lead to a rapid population build-up.

The disadvantage of asexual reproduction arises from the fact that only identical individuals (clones) are produced – there is **no variation** and an asexual population cannot adapt to a changing environment and is at risk of extinction.

4d Asexual Reproduction vs Sexual reproduction

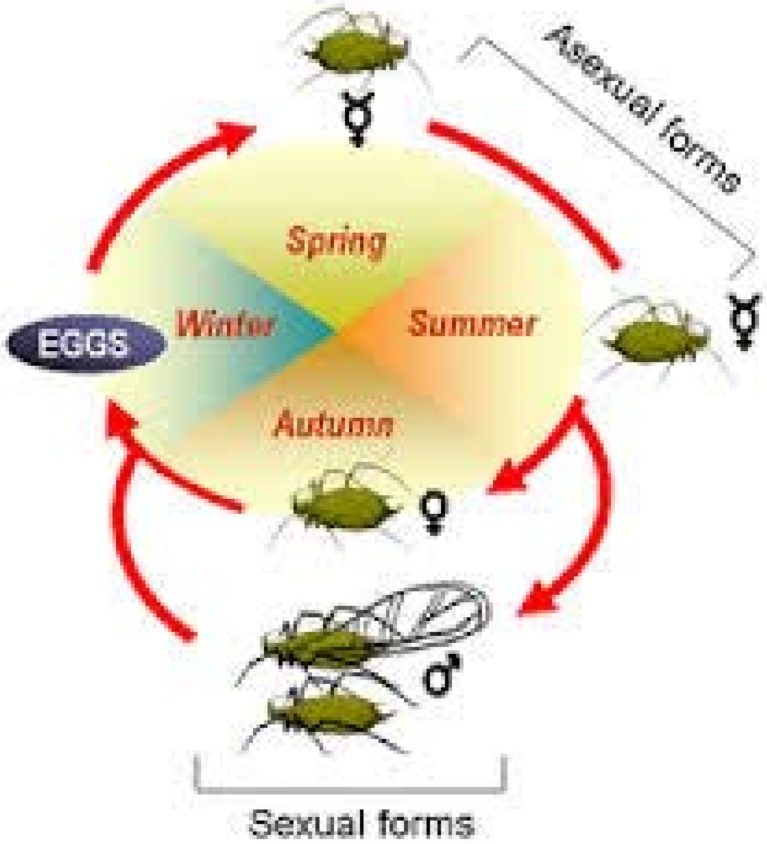
These kittens have been produced through the process of **sexual reproduction.** Some organisms use **asexual reproduction** to produce offspring.

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.

4d Asexual Reproduction vs Sexual reproduction

Asexual reproduction	Sexual reproduction
Single individual is the only parent	Two parents create offspring
The single parent passes on all its genes to the offspring	Each parent passes on only half of its genes to the offspring
The offspring are genetically different	Each individual offspring has a unique combination of genes
Variation is only created by rare mutation	Variation is created in each individual



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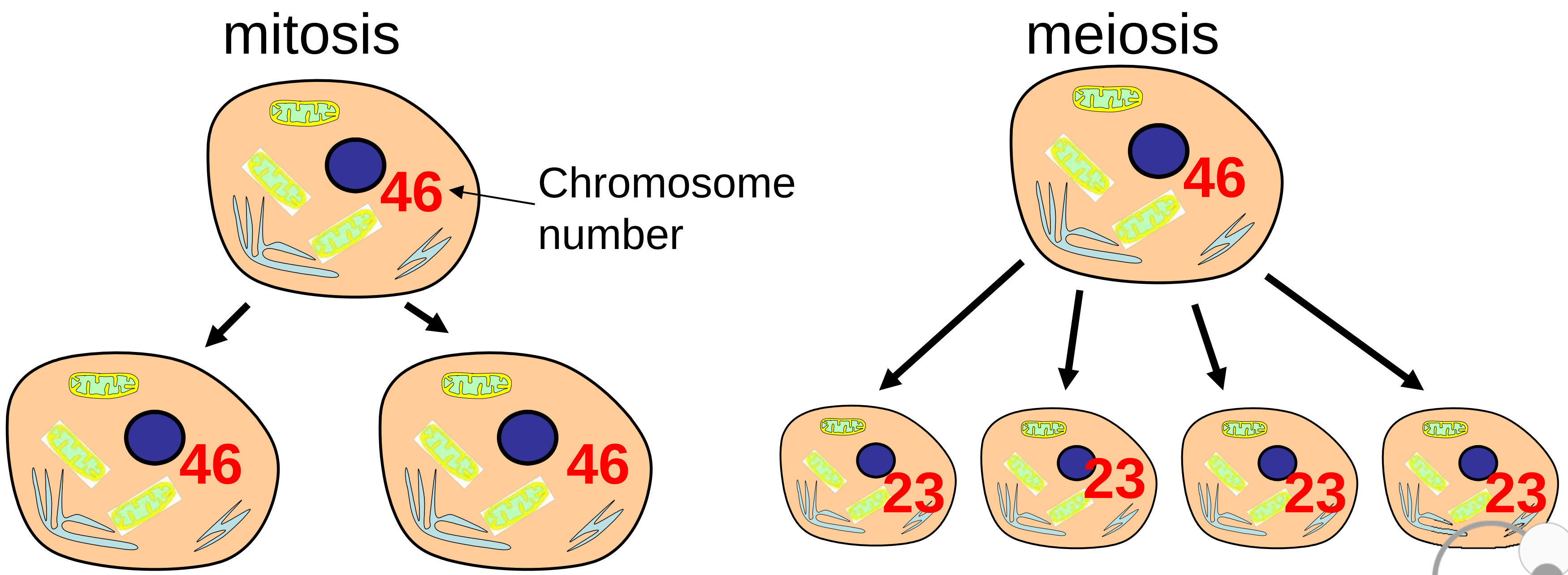
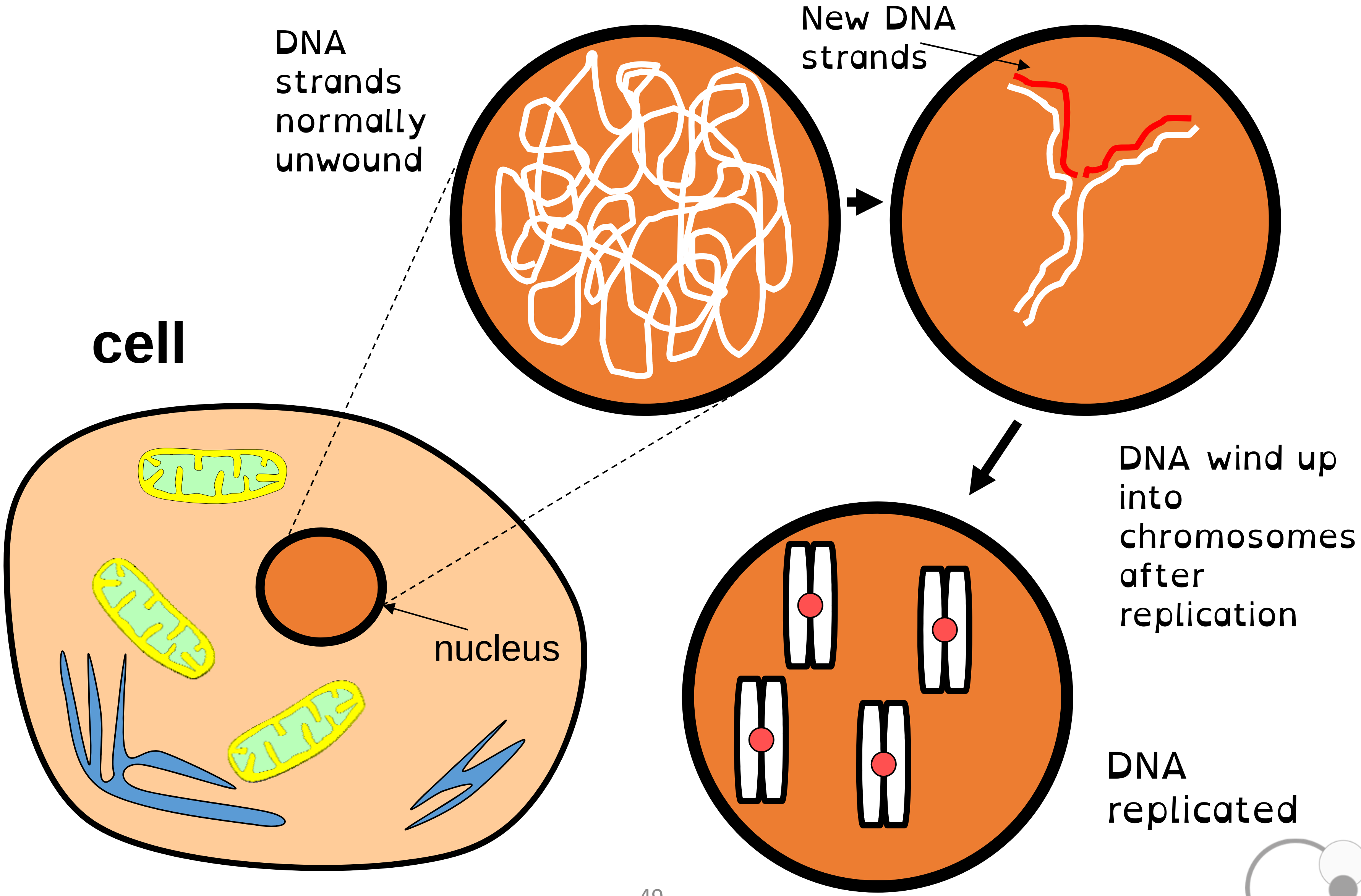
4e Mitosis and Meiosis

Mitosis is the process of cells dividing for growth and/or repair. **Meiosis** is the process of cells dividing to produce gametes.
Mitosis creates **2 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 4 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.



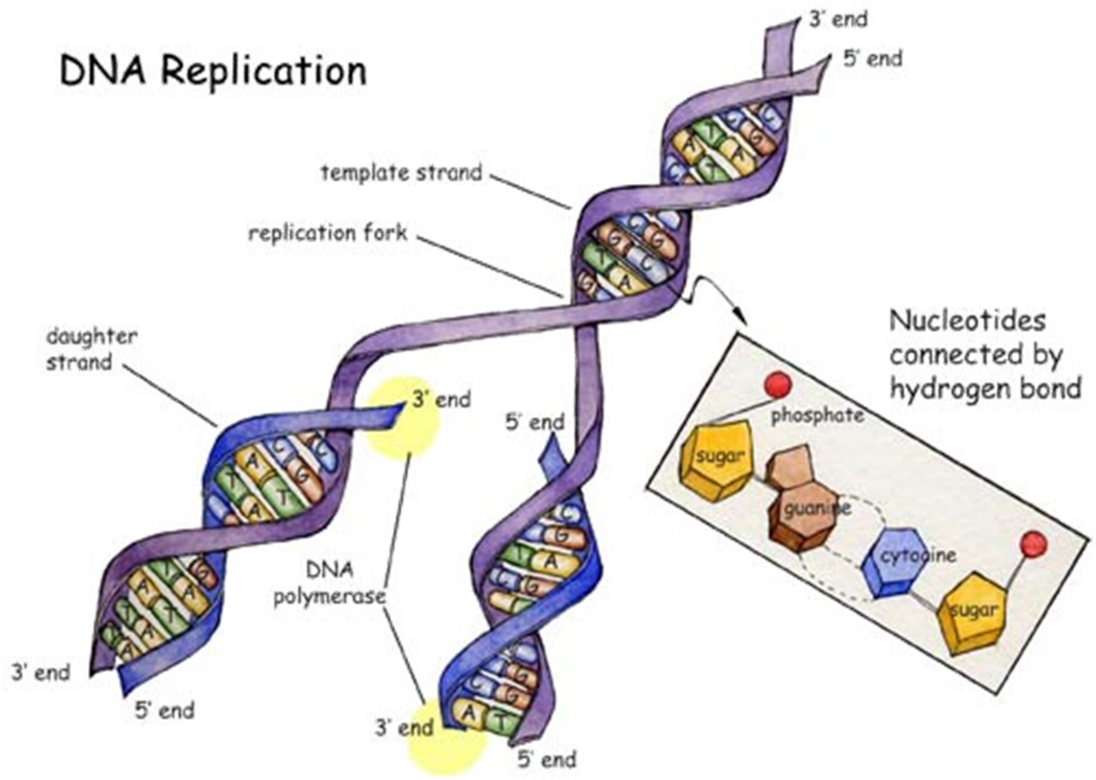
4e DNA replication creates two identical copies of each chromosome



4e DNA replication creates two identical copies of each chromosome

Extra for experts

Before cells divide into two – for either **mitosis** (producing an identical cell for growth and repair) or **meiosis** (to produce gametes) the DNA in each cell's nucleus needs to make an identical copy. Each Chromosome unwinds and the two sides of the DNA chain separate (with assistance from un "unzipper" enzyme. New nucleotides (consisting of a sugar, phosphate and matching base) line up against each exposed base on the pulled apart ladder. Eventually 2 new strands have form, with one original side and one newly formed side each.



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4e

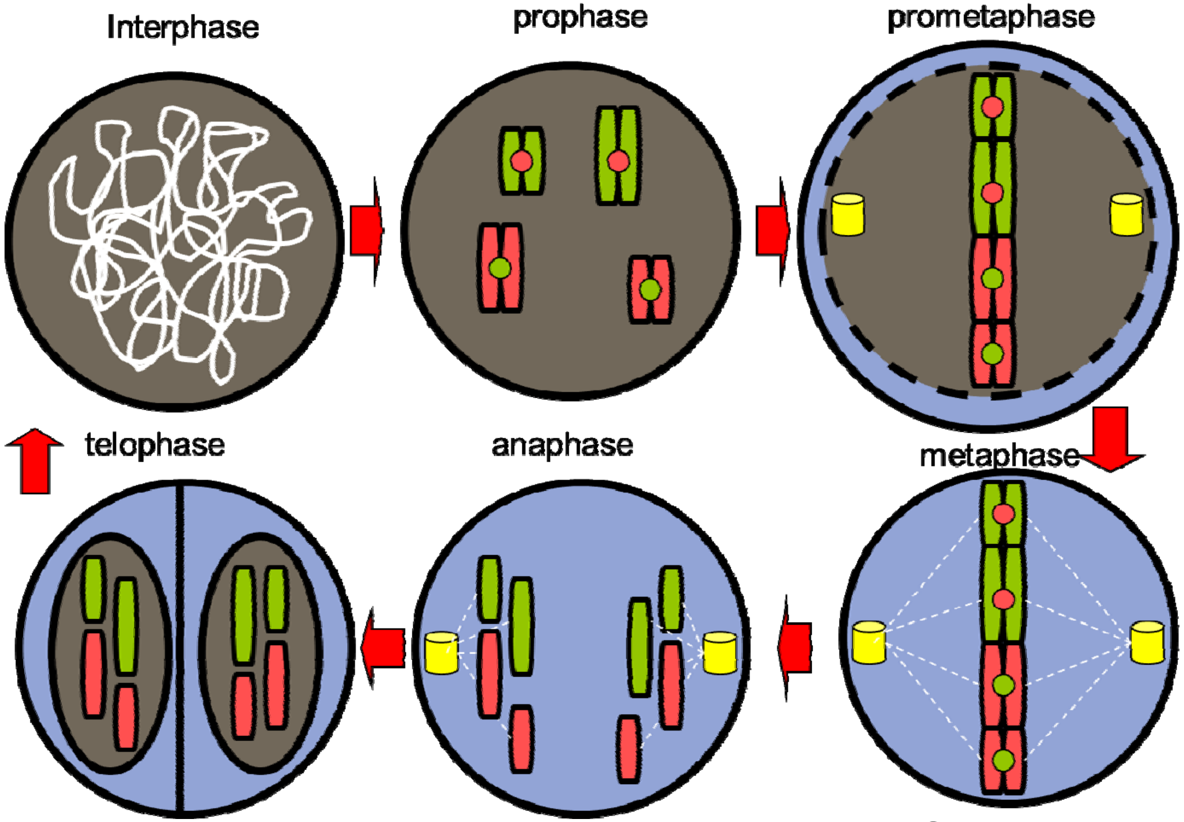
Mitosis creates two identical cells

Extra for experts

DNA replicates into 2 double strands

DNA coil into chromosomes

Chromosomes line up. Nuclear membrane disappears



Cells split by cytokinesis into two. Nuclear membranes reform.

Chromatids pulled apart to opposite ends of cell

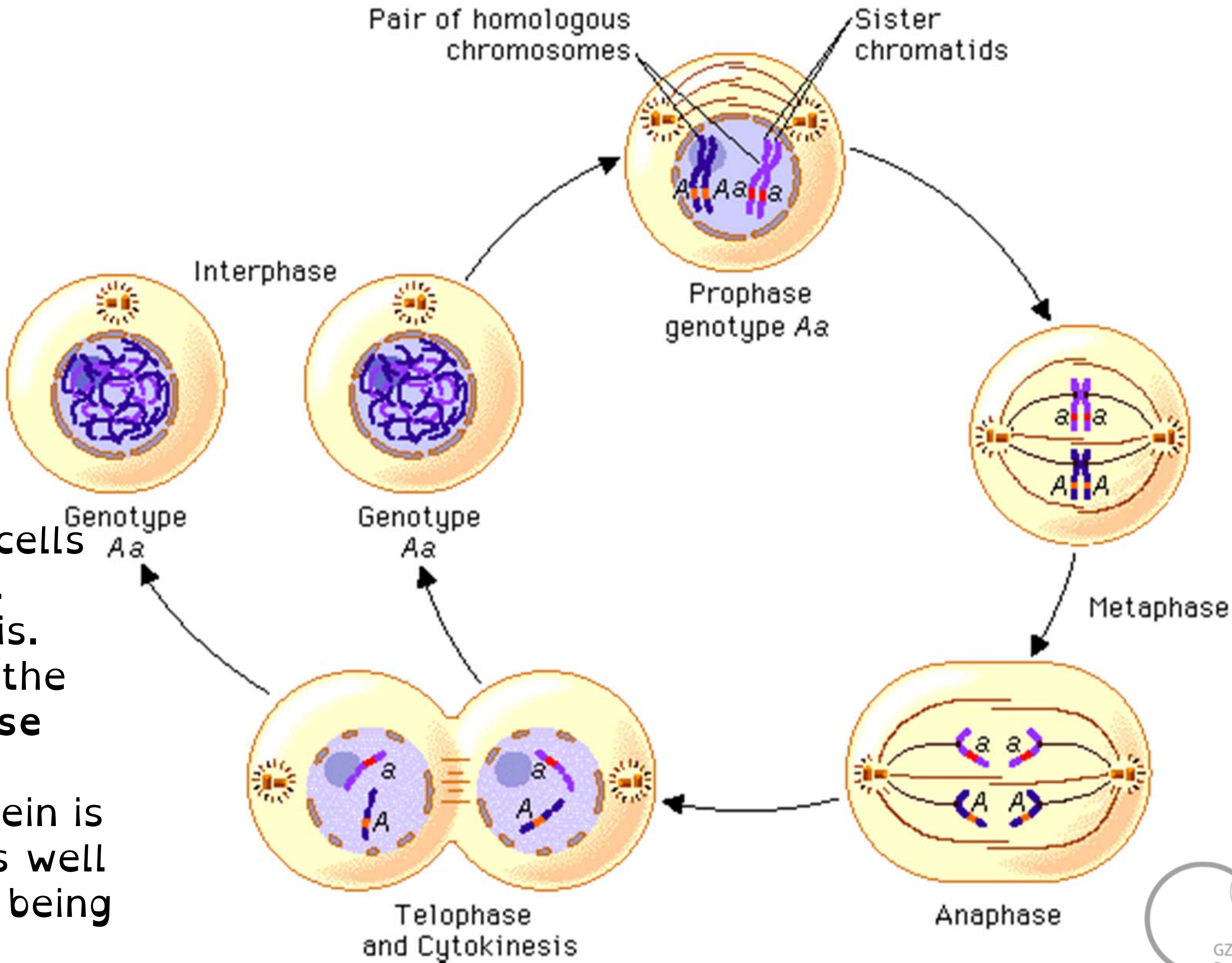
Centrosomes attach spindle fibres to chromatids

4e Mitosis creates two identical cells

Extra for experts

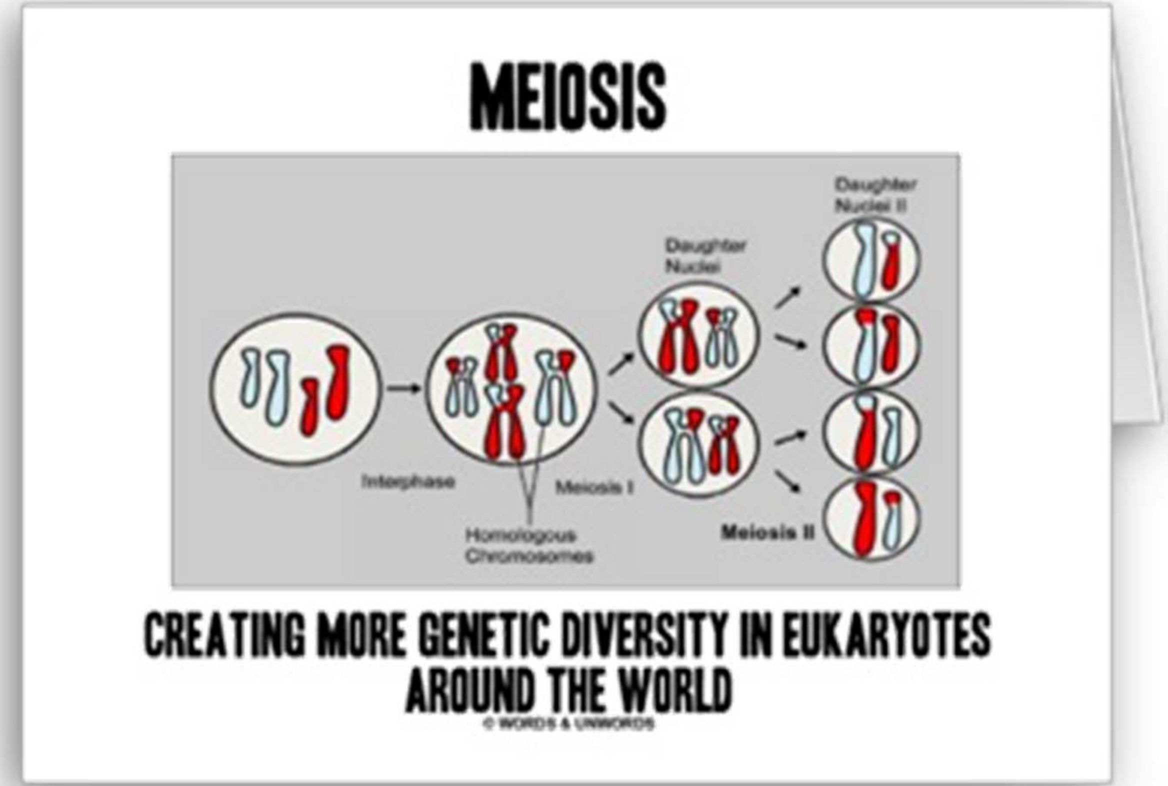
Mitosis is a cycle and each new identical cell produced from an older one is able to undergo mitosis and produce another identical cell as well.

Only part of the cells life cycle is spent undergoing mitosis. Most of the time the cell is in **interphase** where the DNA is uncoiled and protein is being produced as well as cell processes being carried out.



4f Meiosis creates gametes with variation

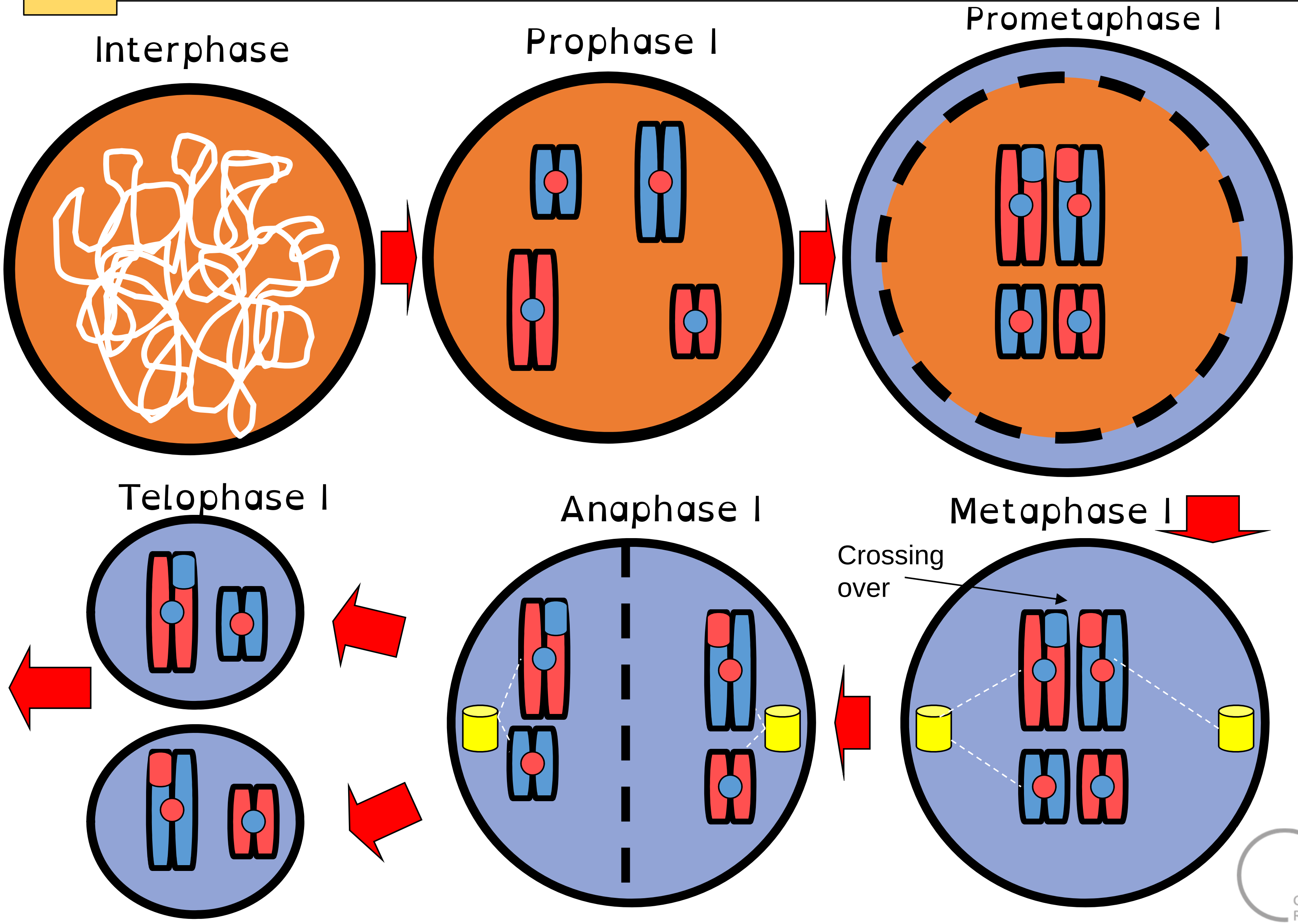
During Meiosis there are three opportunities for increased variation. Firstly when the homologous pairs line up. It is different each time meiosis occurs as one chromosome from each pair will go to each new gamete (called random assortment) – and each contains a different collection of alleles (although 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. Thirdly one half of each doubled chromosome is pulled apart and combined with one of each other chromosome.

4f Meiosis creates gametes with variation – Stage one

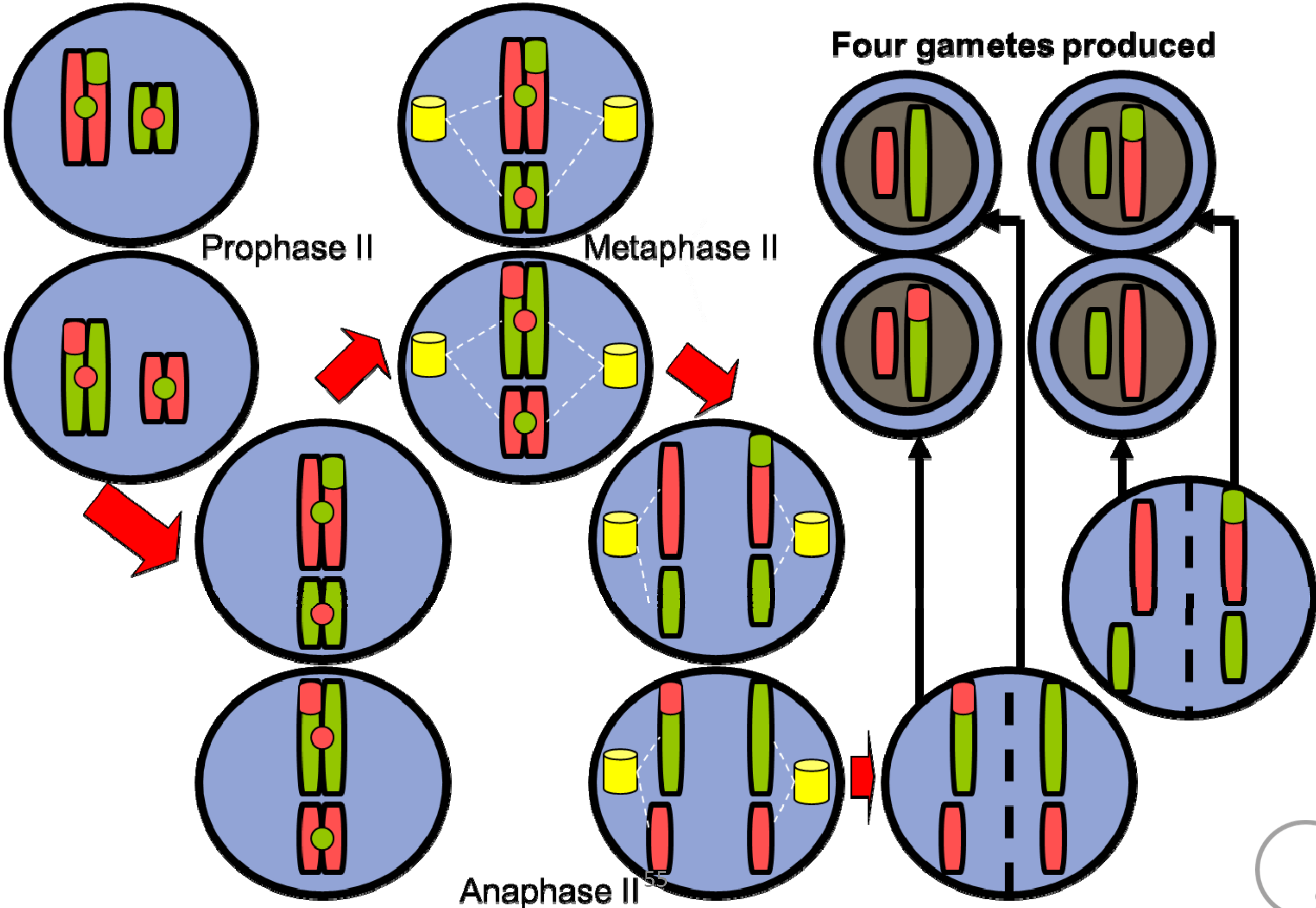
Extra for experts



4f

Meiosis creates gametes with variation – Stage two

Extra for experts



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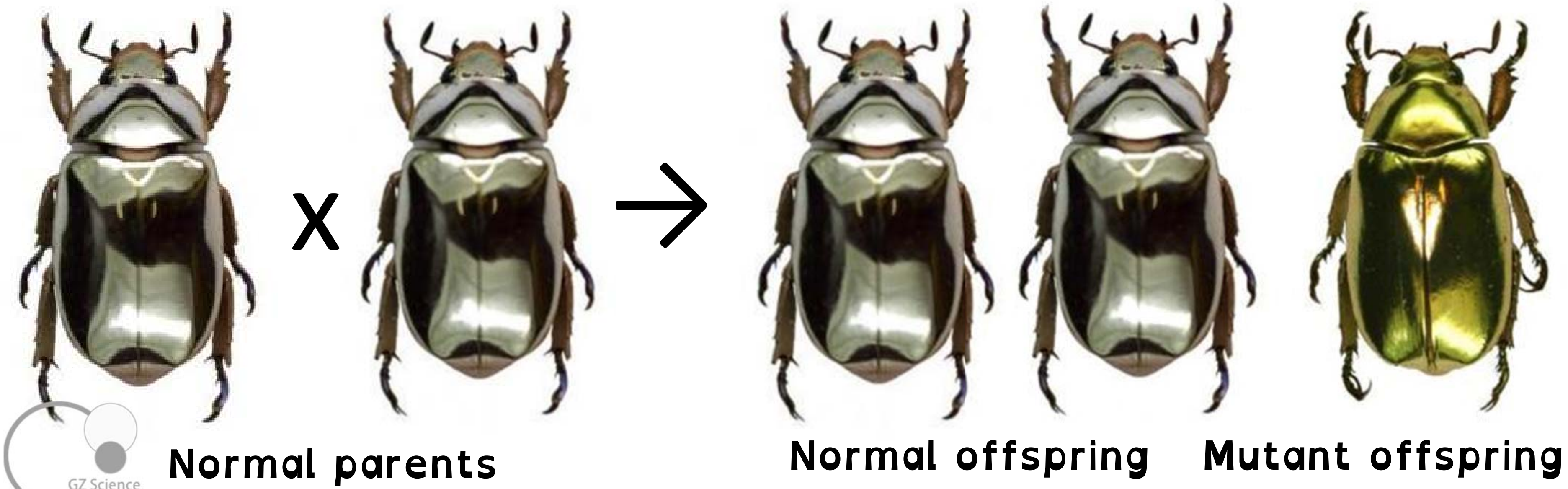
4g Mutations introduce new alleles into a population

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.

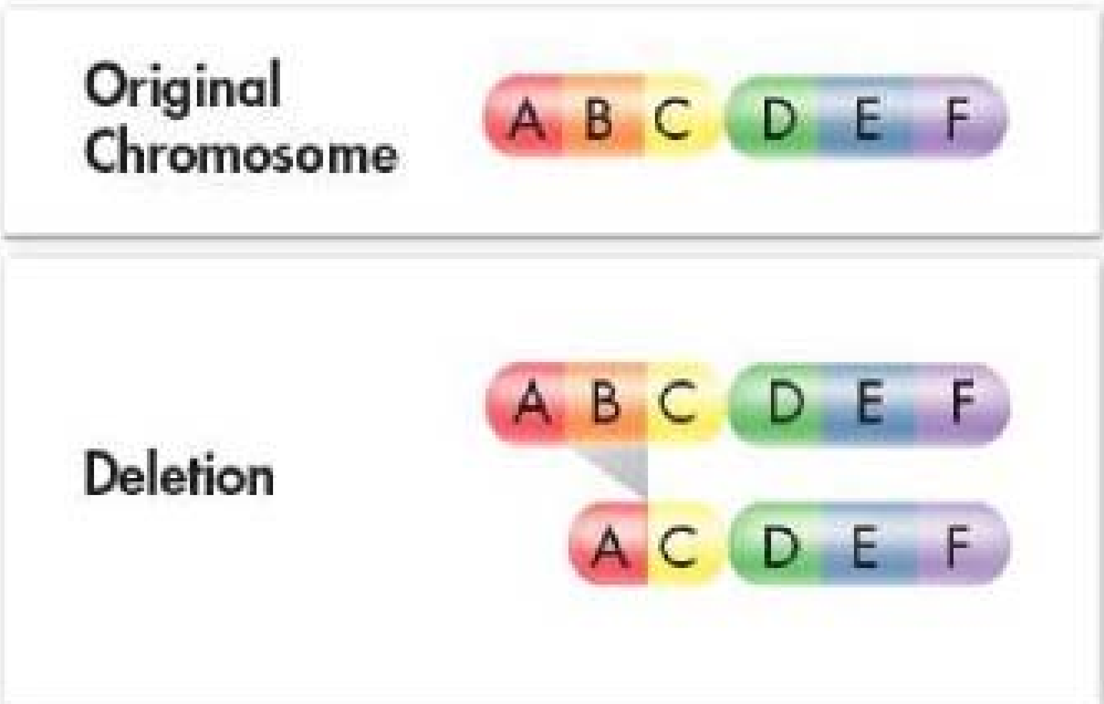


4g

Mutations are caused by a random change in the sequence of bases in the DNA.

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

Mutations can be cause by a single change in one base pair – either deleted, an extra added or a base changed, one segment of DNA or gene, or a whole chromosome added or deleted.



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Causes of Variation Summary

Extra for experts

4g

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.**

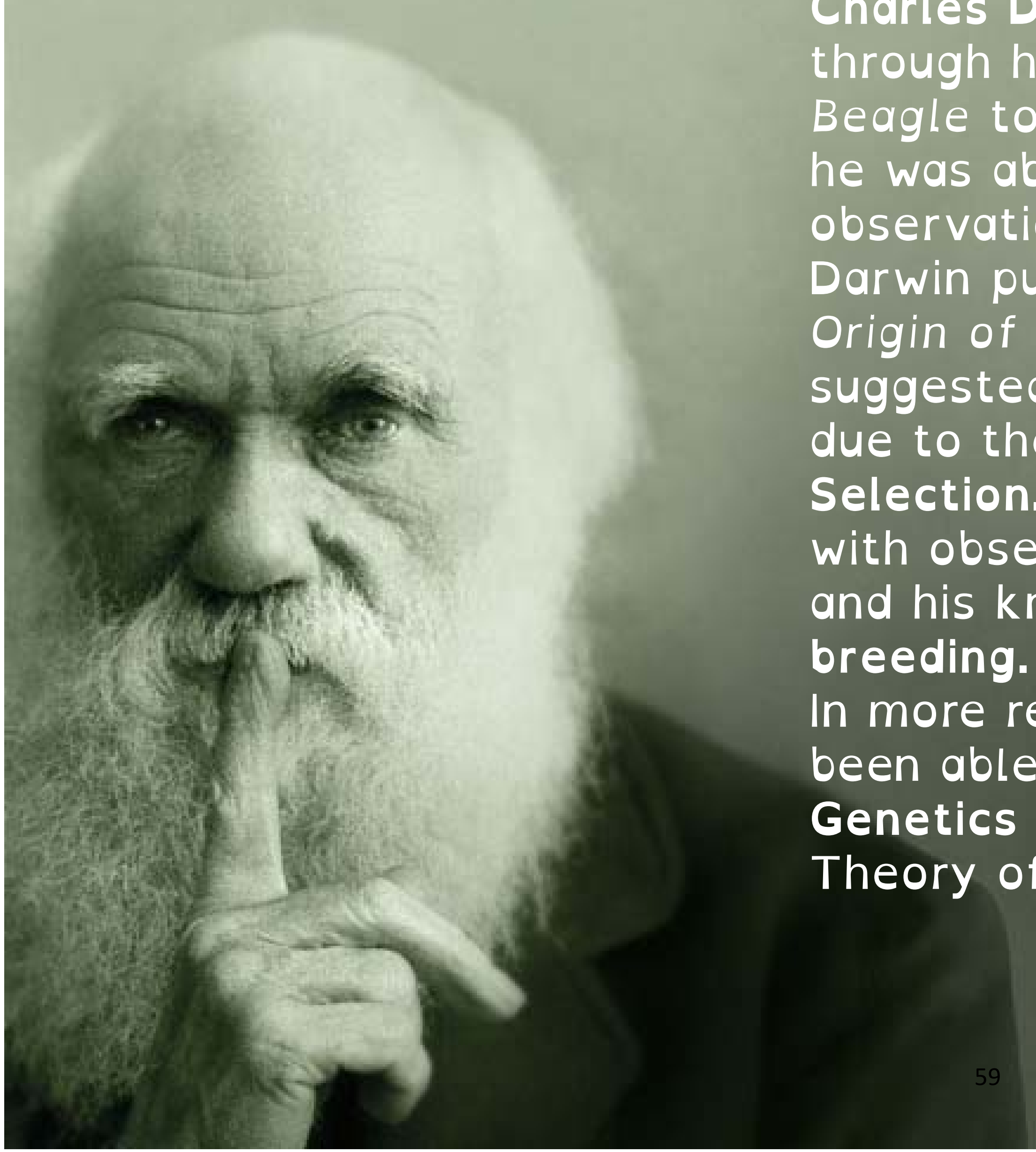
During **fertilisation**, the gametes combine and the resulting offspring will have two alleles – they may inherit two alleles the same, homozygous, and show that characteristic or they may inherit one of each allele, heterozygous in which case they will show the dominant allele in their phenotype.

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.

5a

Charles Darwin and *the Origin of Species*

Extra for experts



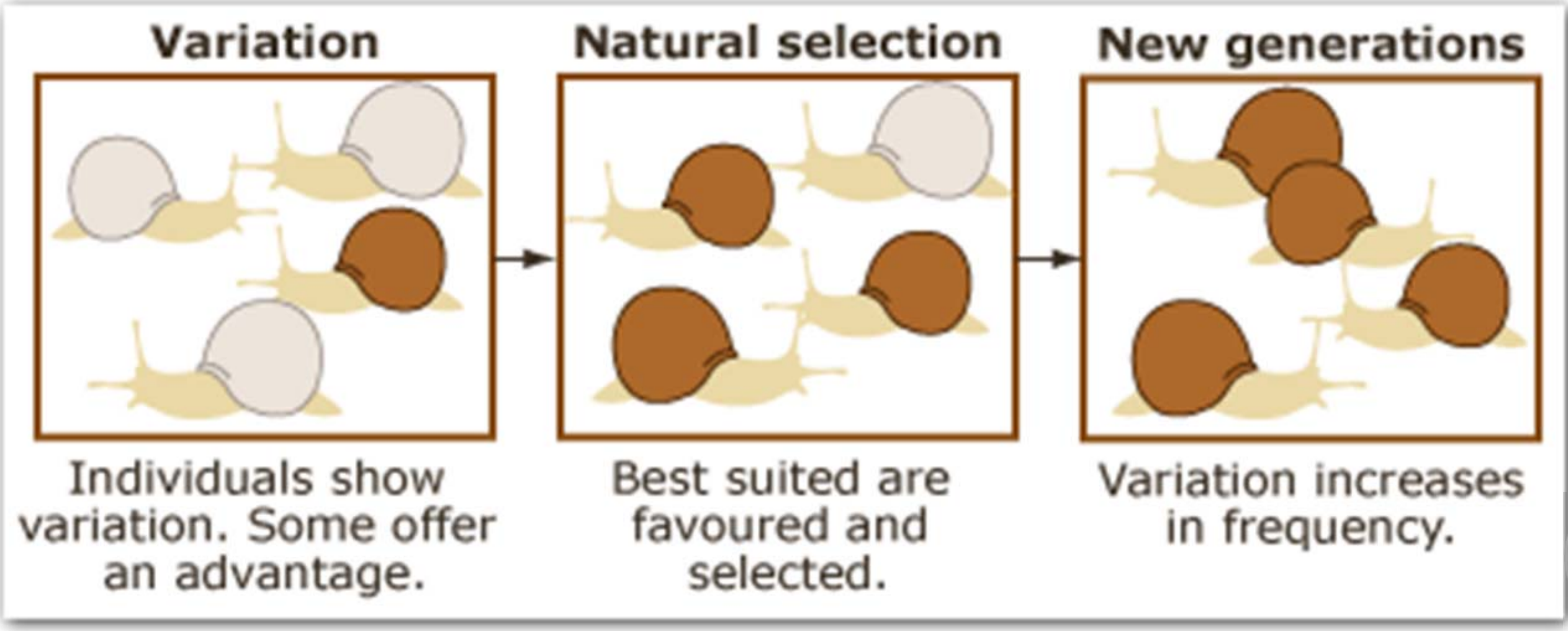
Charles Darwin was a naturalist and through his travels on the *HMS Beagle* to many places in the world he was able to make extensive observations of plant and animal life. Darwin published a book called *The Origin of Species* in 1859 in which he suggested evolution was occurring due to the process of **Natural Selection.** He supported his ideas with observations from his travels and his knowledge of **selective breeding.**

In more recent times Scientists have been able to add their discoveries of **Genetics** to further support the Theory of Evolution.

5b

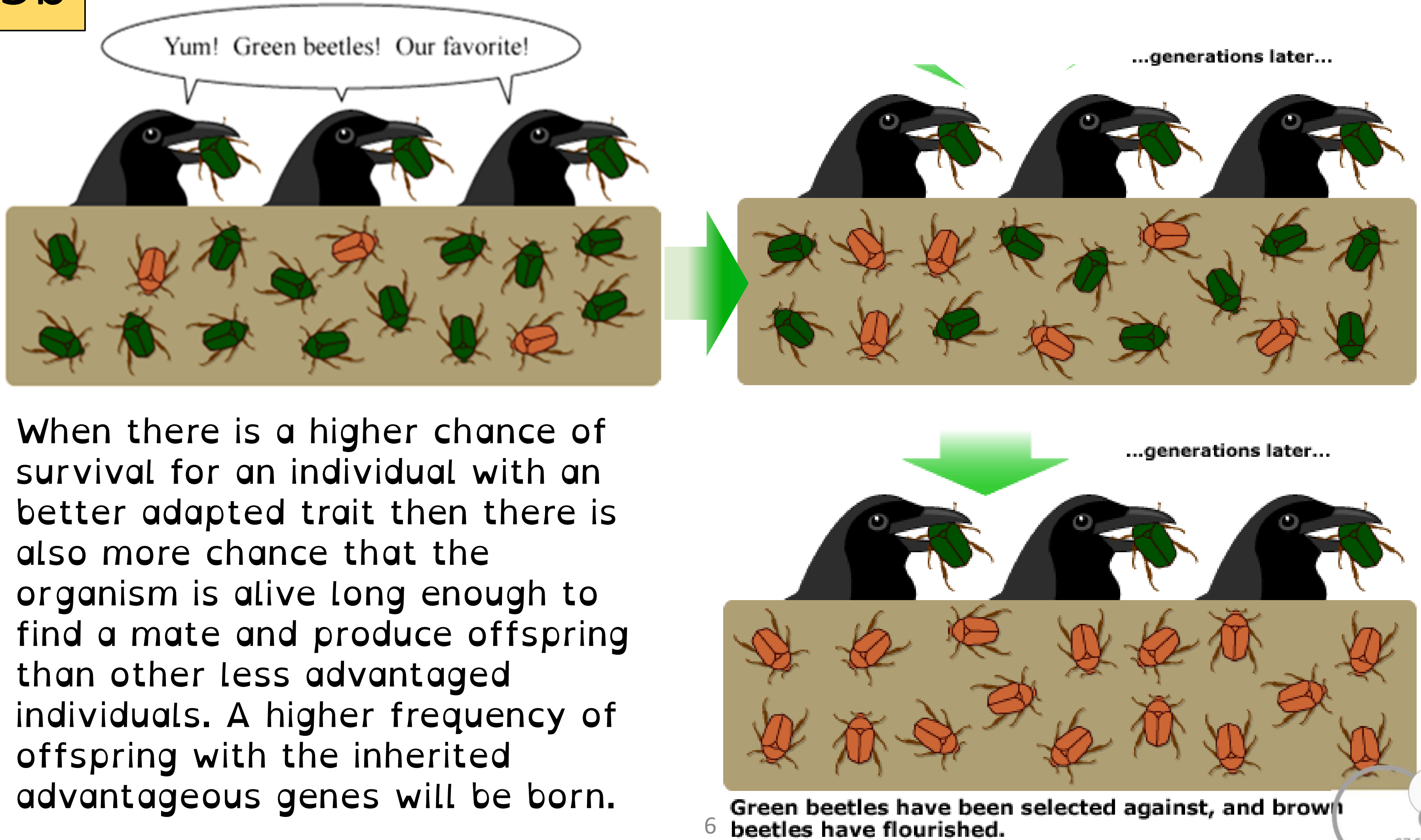
Organisms vary and that some variations give advantages over others in the 'struggle for existence'

Individuals of species occupy a **niche** and they have **adaptations** to survive in their habitats. The adaptations may help them to best obtain food, seek mates, find shelter or escape predators.
Adaptations can be either **structural** – a physical feature of the body, **Physiological** – the way a body works or **behavioural** – the way an organism acts.
Adaptations are traits an organism can genetically pass onto their offspring.
Because there is variation between individuals of a species some individuals may have an advantage over others when one or more of their adaptations is better suited for survival in their habitat.



Variations caused by genes can be passed on to offspring and that genes conferring advantageous adaptations are more likely to be passed on than others

5b



When there is a higher chance of survival for an individual with an better adapted trait then there is also more chance that the organism is alive long enough to find a mate and produce offspring than other less advantaged individuals. A higher frequency of offspring with the inherited advantageous genes will be born.

5b Natural selection

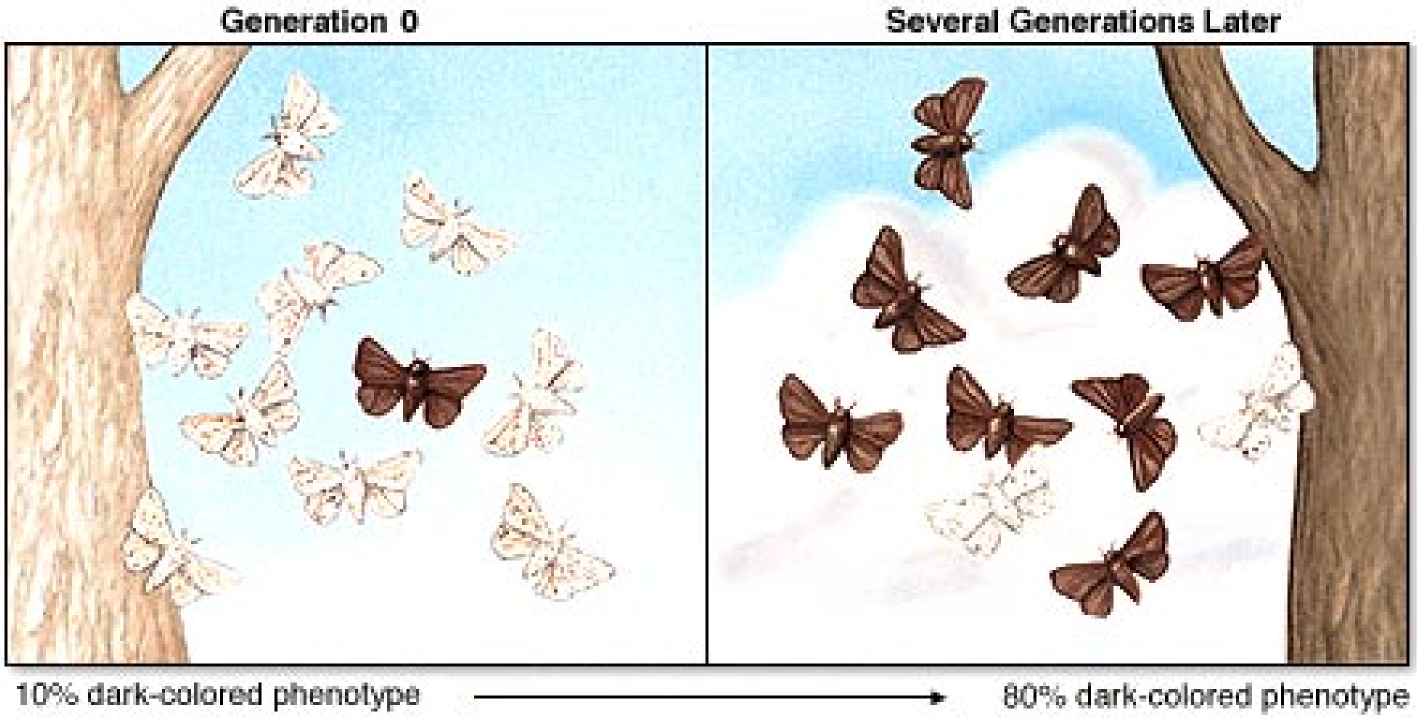
For **Natural Selection** to occur:

1. There must be variation in one or more traits in a population that gives an advantageous adaptation.

2.The individuals with the advantageous trait must be more successful in reproducing and producing more offspring.

3. The trait must be able to be passed on genetically to the offspring.

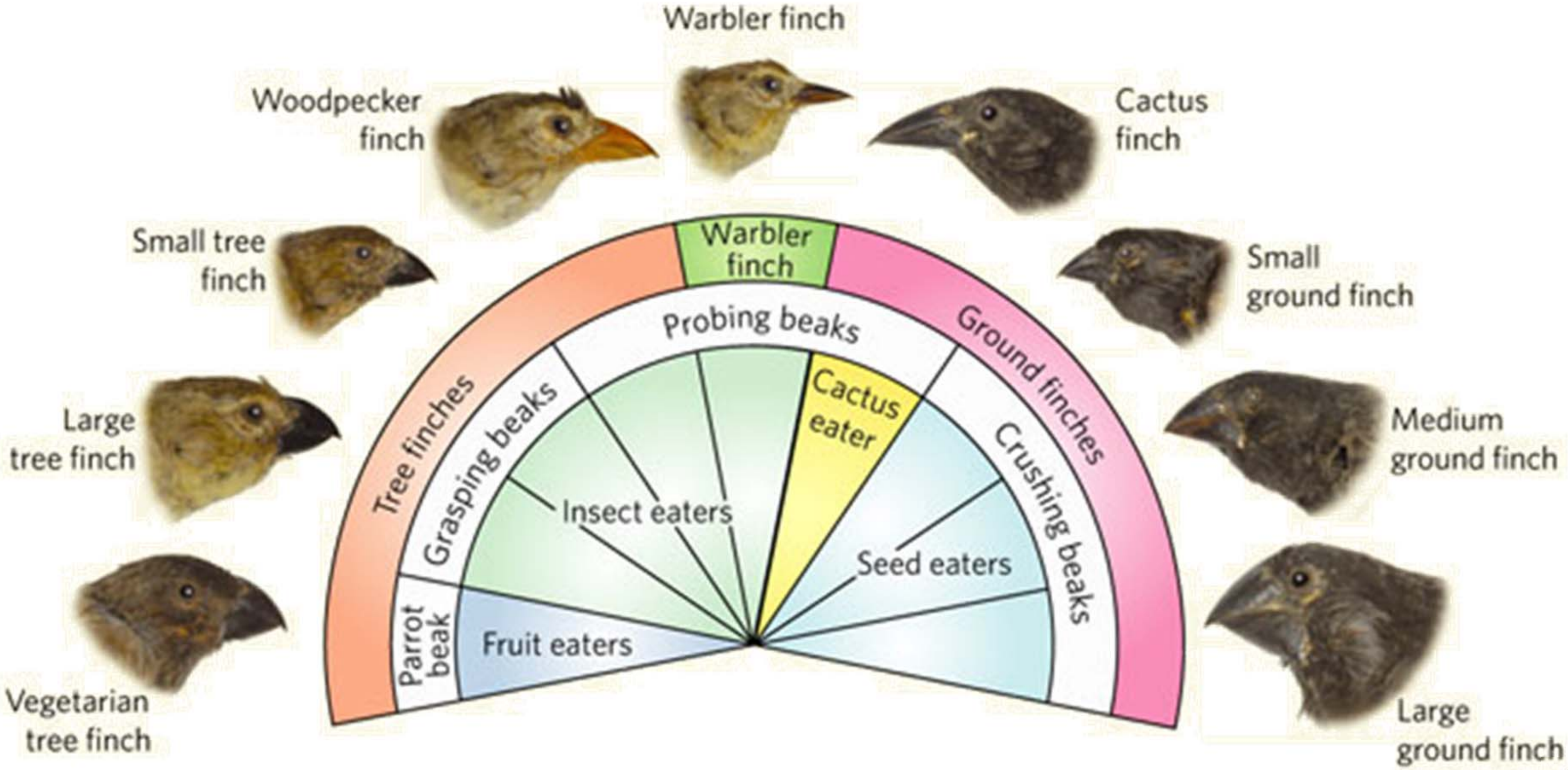
4. The trait must increase in frequency in the population over time.



5b

Evolution is the process of change in all forms of life over generations.

The **Theory of Evolution** proposes that living organisms change in structure and function over long periods of time. A scientific theory is an idea or concept that is supported by large amounts of **evidence.** The evidence is collected from observations and scientific investigations.



The evolution of the Galapagos finches from an ancestral finch

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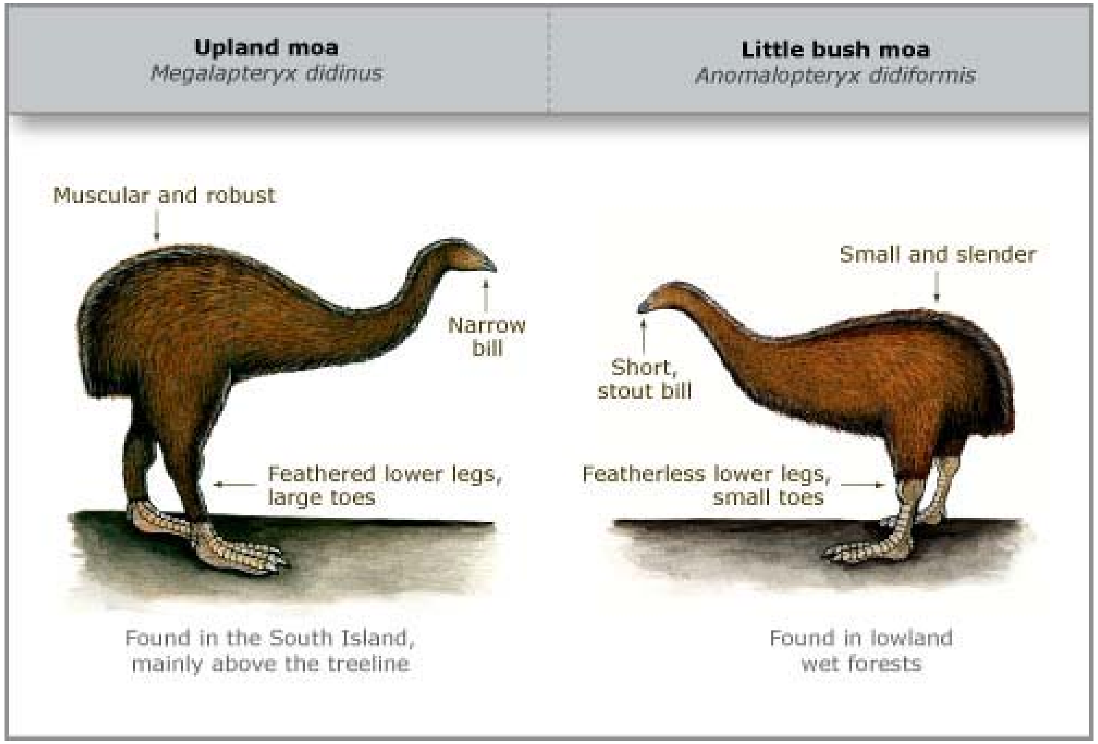
5b Evolution is the process of change in all forms of life over generations.



Moa are a group of Flightless Native New Zealand birds that are now extinct. **Natural selection** is a process that changes the occurrence of particular **physical traits** in a species (and therefore the alleles that produce them) over many generations. The Moa species above have different physical traits but would have had a common ancestor in the past.

The most likely factor that would have caused this change into two different species is **different habitats and environmental conditions** as one species lives in bush and one Moa species on open hills. Physical traits such as a small slender shape to fit under trees and move around easier and therefore be able to escape predators and gather more food, or featherless lower legs to prevent getting waterlogged in the wet forest and therefore keep warmer and not be so heavy to move around would be selected for.

5b Evidence for Evolution

Extra for experts

Scientists have been able to collect evidence from many sources to support the Theory of Evolution:

Fossils show us that there has been changes in the forms of plants and animals on Earth. We have also been able to find fossils of common ancestral animals that join species found on Earth today.

Genetics and DNA structure allow us to compare living organisms and to calculate the amount of differences between species.

Observations of small changes in species occurring within a few generations give us evidence for the process of natural selection.

Biogeography or how species are distributed around the world gives us evidence to the relationships between species.

Artificial selection that humans have used to domesticate animals and plants shows us how species can change.

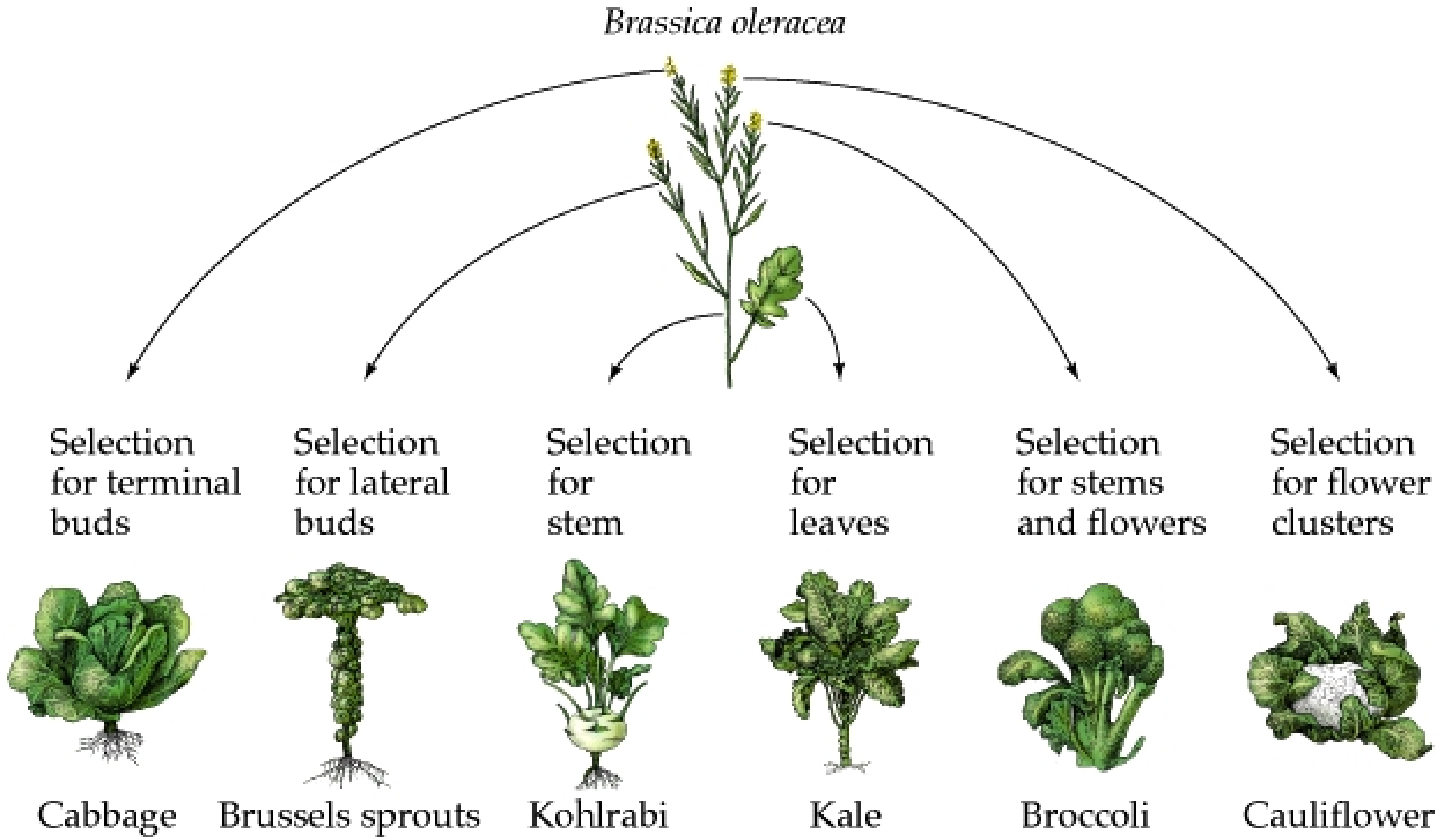
5c

Adaptations are genetically inherited traits that allow species to survive better in their habitat

Structural	Physiological	Behavioural
These are things the animal has in or on its body. E.g.: the long beak of a kiwi to get food in the ground	These are things that the animal can do with its body. E.g.: bad tasting chemicals inside beetles to stop being eaten	These are ways the animal behaves or acts – things that it does to get what it wants or needs. E.g.: fish swimming in groups for safety

5d Humans can exploit variation through artificial selection

Humans have been able to **domesticate** plants and animals by actively selecting advantageous traits in a wild species and repeatedly breeding those individuals that exhibit it. After many generations the domesticated species looks distinctly different from the original wild ancestor. This process is known as **artificial selection.**



6a New Zealand plants and animals are unique due to them evolving in geographical isolation

For a long time in New Zealand's geographical history it formed part of a land mass called **Gondwana,** also composed of Australia, and Antarctica (as well as Africa, South America and India at an earlier stage). About 85 million years ago the plate that New Zealand sat on top of broke away from Gondwana and moved North, through the process of **plate tectonics**, and has remained in isolation ever since.

85 Million Years Ago | **60 Million Years Ago** | **Today**

6a

Ancestors of New Zealand's plants and animals arrived at various times in the past

When New Zealand first broke away from Gondwana it was in the form of a giant land mass called Zealandia and populated with animals and plants - all of which had previously evolved on Gondwana. Zealandia sat upon a thin crust and over time scientists believe it almost completely (if not entirely) submerged. Parts of it that we now recognise as New Zealand were raised up from the ocean due to active plate movement under it about 30 million years ago. It was after this time that New Zealand was populated by birds, insects, reptiles and plants that either flew or rafted over from Australia or South America

6a Ancestors of New Zealand's plants and animals arrived at various times in the past

From the original pioneers that populated New Zealand after it re emerged from the sea we now have animals such as tuatara, kākāpō, wrens, moa, primitive frogs, geckos, dinosaurs, primitive groups of insects, spiders and earthworms as well as some types of plants - all of which had evolved to various degrees. Other species of animals either flew across vast distances from surrounding countries or were transported across by the sea at various times in the next 25 million years but **no species of Mammal** (aside from two species of bat that flew) ever made it across to New Zealand until Humans arrived around 400 years ago.

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6a New Zealand's Plants and Animals have had to adapt to its constantly changing conditions

Ever since New Zealand broke away from Gondwana it has had a very **disruptive geographical history.** At various times in its past New Zealand has been totally (or almost completely) submerged under the ocean, encountered a series of ice ages which covered the country in ice, snow and glaciers as well as had ranges of mountains pushed up due to tectonic plate movement and eroded back down again. During this time New Zealand's animal and plant species have had to adapt and evolve to these changing conditions, some becoming **extinct** but others remaining to the present time.

6a New Zealand's plants and animals have evolved in the absence of Mammals

New Zealand's animals have evolved without the presence of Mammals and any ground predators.
This has created some special characteristic features in our animals. Many of our bird species have become flightless because they have not needed to fly away from predators.
Niches or lifestyles filled by Mammals in other countries have been filled by birds, insects and reptiles in New Zealand.

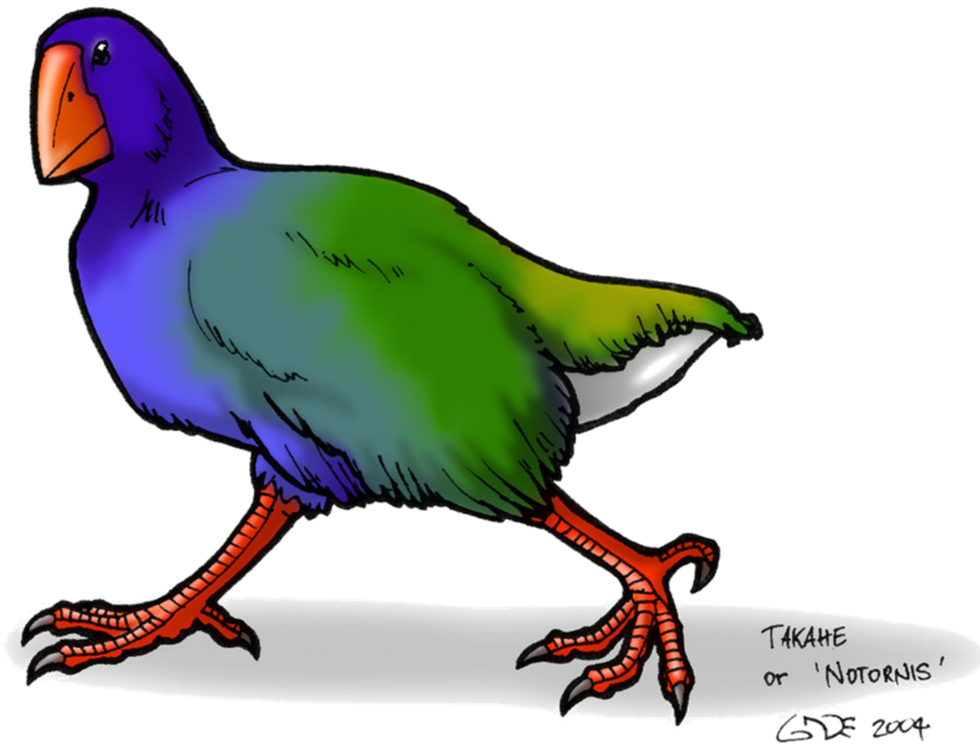
For example the kiwi occupies a niche similar to a badger - lives in burrows, eats worms and other invertebrates (animals without an inside skeleton) , the Moa occupied a browsing niche similar to deer, Weta and the Short tailed bat occupied a niche that is taken up by mice elsewhere.
As a consequence many of our species look quite different from related groups of animals and plants in other countries.

6b

What is the advantage of not flying?

Flight in birds is an adaptation to escape from predators and move around quickly. It requires a lot of energy, which means birds who fly must find and eat a lot more food than non flying birds. Birds who fly also need to be light so their size and weight is limited.

New Zealand had no mammal predators so birds did not need to fly to escape. The benefits of not flying out weigh those of flying. Birds which did not fly had a **survival advantage** over those that did and produced more offspring. New Zealand flightless bird species could also become heavier and be suitable for niches (jobs) that were occupied by mammals in other areas of the world.



New Zealand has a large number of **endemic** plants and animals – that means not only are they found in New Zealand (**native**) but they are also found in no other place. There many thousands of fungi and insect species that are endemic plus around 70 birds,80 skinks and geckos, 38 freshwater fish, seven frogs, three bats and two species of tuatara.

6b Our unique plants and animals - Kakapo

The Kakapo is the only flightless and nocturnal parrot in the world. The Kakapo is also the heaviest parrot in the world, weighing up to 3.5 kilograms.

Due to habitat destruction and predation there are now only approximately **62 Kakapo left.** These remaining birds have been **relocated** to several predator free island habitats, where the birds can breed in safety.

6b Our unique plants and animals - Tuatara

Tuatara are rare, medium-sized reptiles found only in New Zealand. They are the only living members of the **Order Sphenodontia,** which were a group of reptiles that lived on Earth about the time of the first dinosaurs, some 200 million years ago.

Although the species of Tuatara has been around for a very long time it appears to be nearly **identical** to its ancestors that lived over 200 million years ago.
It has been ideally adapted to its habitat and there has been no environmental pressure to change.

6b

Our unique plants and animals - Kiwi

The kiwi are a flightless, nocturnal group of birds related to the extinct Moa and the Emu, which form part of a group called the **ratites** which now live in countries once forming part of Gondwana.

There are 5 main species of Kiwi in New Zealand: the brown kiwi, the rowi, the tokoeka , the great spotted kiwi or roroa and the little spotted kiwi.
They all eat invertebrates (worms, insects etc) and fruit.
The females produce an enormous egg which the males **incubate.**
The chicks must survive on their own as soon as they are born.

6b Our unique plants and animals - Tui

Tūī belong to the **honeyeater** family, which means they feed mainly on **nectar** from flowers of native plants such as kōwhai, pohutukawa, rātā and flax. Occasionally they will eat insects too.

Tūī are important **pollinators** of many native trees and will fly a long way for their favourite foods, especially during winter. Flowers that are red or yellow often indicate that a plant is pollinated by birds.

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6b Our unique plants and animals – native frogs

New Zealand has four species of frogs including Hochstetters Frog, and Archey's Frog. They all exhibit very **primitive traits** showing very little or no webbing between their toes. They have no free swimming tadpole stage, and they spend much less time in and near water than other more "advanced" frogs found else where in the world.

All or our frog species are rare and **endangered.** Two species are found only on a few small isolated islands of the coast. They have been affected by habitat destruction and the introduction of predators like many other endangered New Zealand species.

6b Our unique plants and animals - Weta

Weta are mainly herbivorous and nocturnal Insects. There are more than 70 species of weta in New Zealand and they live in a variety of habitats including grassland, shrub land, forests, and caves. They dig holes under stones, rotting logs, or in trees.

Weta are similar to many species of plant and animals in New Zealand in that one ancestral species has **radiated** and **adapted** into many species to fill available **niches** due to the absence of many types of organisms found in other countries.

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6b Our unique plants and animals – Short-tailed bat

The short-tailed bat is an ancient species unique to New Zealand and only one of two species of Mammal to have reached the Island (the other being the long tailed bat that arrived at a later stage). The bats are omnivorous and nocturnal. The bats are also important pollinators of the woodrose, a rare parasitic plant which grows on the roots of trees on the forest floor.

Most bats catch their prey in the air but the short-tailed bat has **adapted** to **ground hunting** and is one of the few bats in the world which spends large amounts of time on the forest floor. It uses its folded wings as `front limbs' for scrambling around on the ground.

6b Our unique plants and animals - Kauri

Ancestors of the Kauri were probably present on the New Zealand land mass 85 million years ago when it was first breaking away from Gondwana . The Kauri has been able to survive a succession of ice ages, land sinking and mountain building periods on New Zealand, as confirmed by fossil trees and Kauri gum found in archaeological excavations. At one stage the Kauri covered vast areas of New Zealand whereas now its mainly confined to the northern parts of the North Island.

The huge Kauri belongs to the plant family of **podocarps** which are a type of **conifer** that evolved before the flowering plants. It is a slow growing tree but it can live for over 1000 years.

6b

Our unique plants and animals - Rimu

Like the Kauri, the Rimu belongs to the Podocarp family of conifers. The Rimu is an important part of the New Zealand bush ecosystem and birds rely on its red berries it produces for food. Some species such as the kakapo **synchronise** their breeding with the years that Rimu produce their most fruit, called the Mast, so they have sufficient food to feed their chicks.

6b Our unique plants and animals - Cabbage Tree

The cabbage tree, belonging to the **monocot** flowering plants group, was a relatively late arrival to New Zealand with it's ancestor most likely to have been washed ashore or carried over from a more tropical area around 15 million years ago in the warm **Miocene** era. Since then the plant has adapted to various habitats in New Zealand and can be found throughout most of the country.

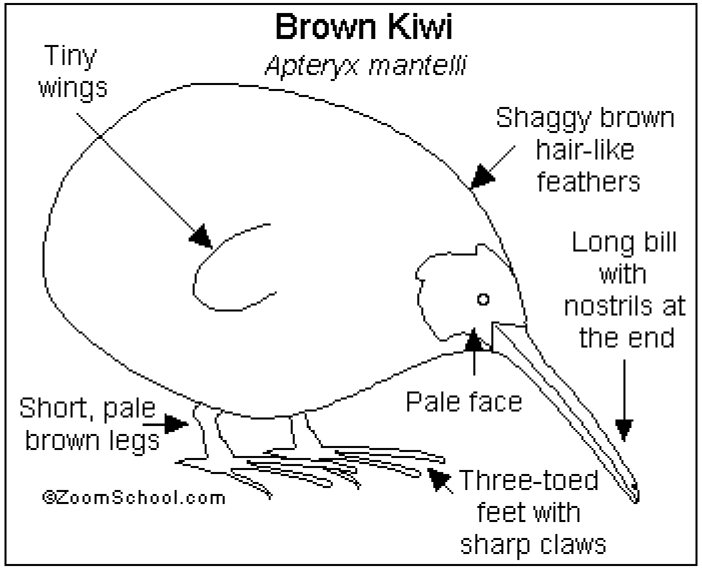
6b Our unique plants and animals – ponga (silver fern)

The Ponga is an endemic plant but also arrived late in New Zealand's history during the Pliocene around 4 million years ago. The Ponga is found on the main islands of New Zealand and many surrounding islands. It is a member of the fern group which produce spores and grow in habitats with sufficient water

6c Species have adaptations to allow them to survive better in their habitat

Plant / Animal Name ...Brown Kiwi....... **scientific name** ..Apteryx mantelli

Drawing



Habitat – where does it live? New Zealand - In the bush in isolated areas. Especially northland and the Coromandel peninsular. In the undergrowth, in burrows

Activity – when is it active?

The kiwi is active at night in the bush, it is nocturnal.

Feeding type – What is it? And what food does it need to survive?

It is a carnivore. The kiwi uses it long beak to dig into the soft earth of the bush to collect and eat earthworms and small invertebrates (insects etc)

Adaptations – what is special about the organism to help it survive?

Physiological – how its system works –it produces a large egg with lots of yolk to help the baby kiwi grow to a big size before it hatches – then it has to look after itself

Structural – special body features – nostrils at the end of the beak to help it smell for food when it is in the ground

Behavioural – how it acts – it hides in a burrow during the day and feeds at night to stay away from predators

6d

The main threats to our native animals

What is Killing our Native Animals?

- Introduced species such as rats, stoats and possums killing the birds and/or their eggs
- Introduced competing species such as rabbits and possums eating the birds food
- Human destruction of bird habitats

Our animals in New Zealand evolved in the **absence** of ground predators or mammals so they have not developed adaptations to defend themselves as well as other species in the rest of the world have. Our birds, that have become flightless, heavy and slow breeding, have been especially vulnerable to **introduced predators.** Large areas of our native forest have been burnt and cut down as well as wetlands drained to convert to farmland, since humans have arrived. Some of our **endangered species** are confined to small marginal areas of land.

6d The Kakapo case study

Kakapo were once spread all over New Zealand in large numbers before humans arrived on New Zealand. The species evolved without mammal predators. The nocturnal behaviour (active at night time) and bush camouflage protected it from its main predator, the giant Haast eagle – that hunted in the day by sight.

The introduction of mammal pests that ate and killed kakapo as well as the human killing and eating of kakapo greatly reduced numbers of kakapo. The destruction of the habitat and food of the kakapo by humans and pests also had an impact. Kakapo have not evolved to escape predators and they cannot fly to escape. They are more sensitive to predators than birds that have evolved with them. Kakapo are slow breeding and have small numbers of chicks – they cannot replace lost birds quickly. There is low genetic variation and diversity of the remaining birds so there are less healthy chicks produced and a low breeding rate. It is harder for males to find partner to mate with and a limited habitat to live in and get enough food, especially mast Rimu required during breeding.

6e The ways humans can conserve and protect our environment

What can we do to save our Plants and Animals?

- ❑ Pest control by trapping or poisoning
- ❑ Fencing off areas such as Maungatautari to make a safe pest free area for birds.
- ❑ Plant more native trees and protect habitats that remain
- ❑ Educate New Zealanders about conservation

Breeding programmes and habitat protection projects have picked up pace in the last few decades to protect and save our most **endangered** species. Pest free areas have been created along with more marine reserves. Some species such as the Kiwi are making a gradual recovery in these areas, others such as the Kakapo and Maui's dolphin have so few remaining individuals left that saving the species from **extinction** becomes difficult. Education and involvement in conservation can help us save the unique plants, animals and habitats that New Zealand has been given.

6e

Maungatautari Ecological Island trust – A case study

Part one - Maungatautari is a bush covered mountain surrounded by farmland in the Waikato. It was once the home of many new Zealand species but due to introduced predators such as rats, possums and stoats, and habitat destruction many species became extinct and the mountain became empty.

Over a decade ago a number of farmers and conservationists came up with an ambitious idea to surround Maungatautari Mountain with predator proof fencing and begin intensive pest control to remove every single mammal pest.

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6e Maungatautari Ecological Island trust – A case study

Part Two - Not that many years later, with a huge effort from volunteers and the generosity of local land owners and Iwi, Maungatautari started to come alive once more.

The Hihi (stitchbird), takahe, Tuatara, Kiwi, saddleback and the North Island Robin are just some of the species introduced back into the safe predator free sanctuary.

Many species of Reptile, plants and Fungi once thought extinct have also made a remarkable recovery as well. Maungatautari sanctuary has become Taonga (treasure) for all New Zealanders