2020
Version

With 2019 NCEA
Exam included

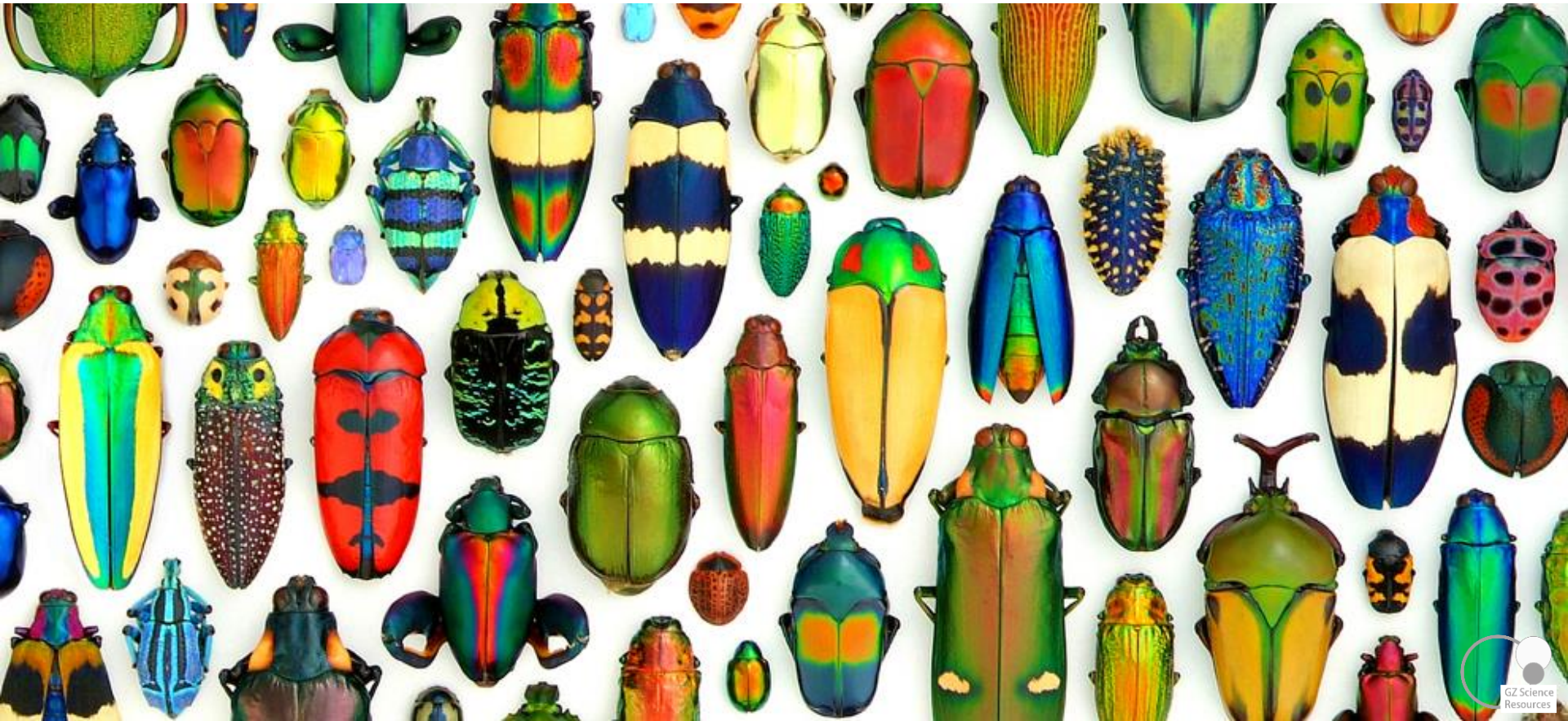
Science AS 90948
S1.9 Genetic Variation

GZ Science
Resources

Part Two

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

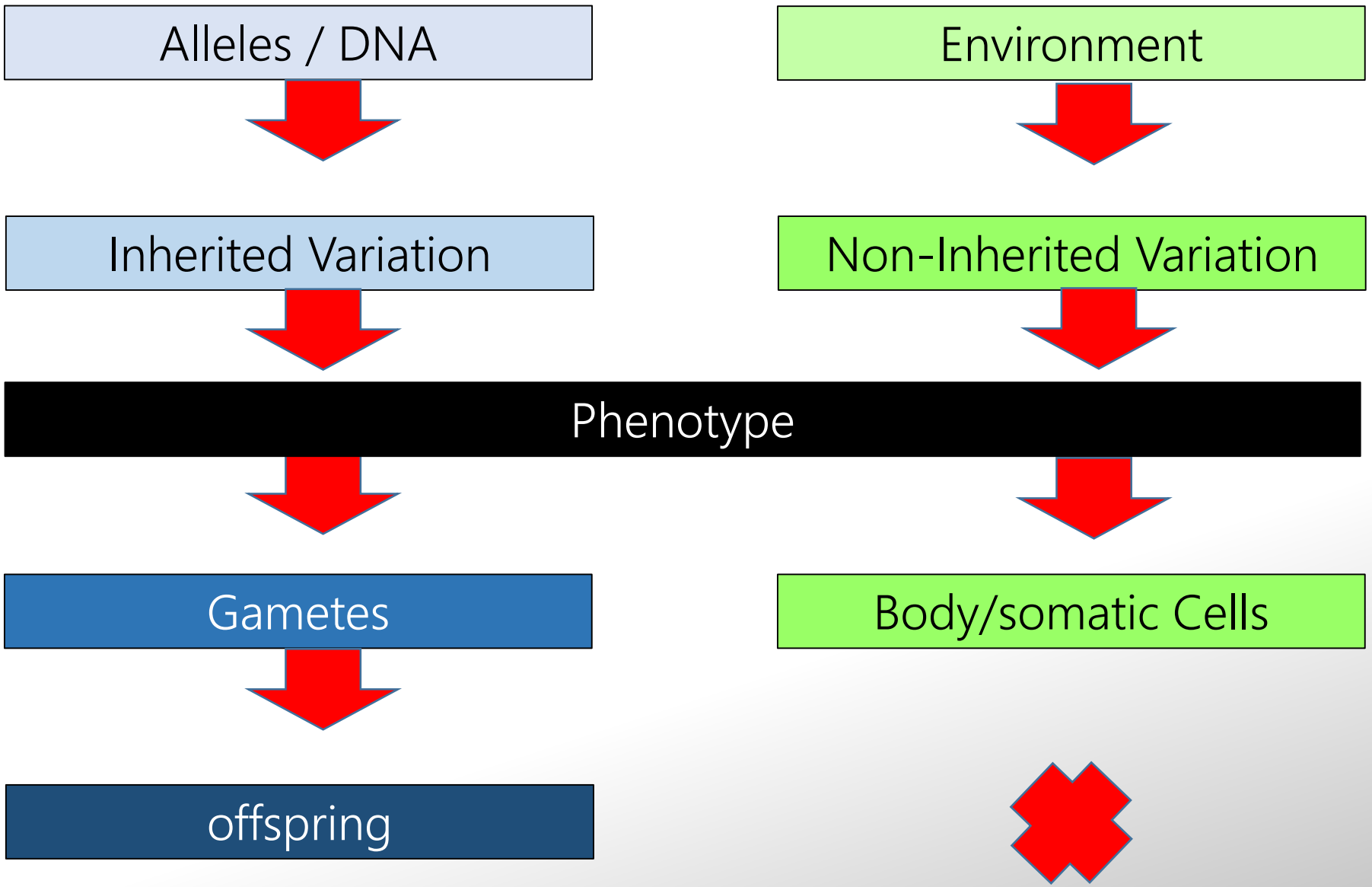
As a species, Humans all have the same set of genes. However, each individual, except identical twins, has a different combination of alleles inherited from both parents and this creates **variation**. Variation of traits causes each individual to look different from another and in many cases behave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

This Lion has scars on his face due to environmental effects, and these will not be passed down to his 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.

Environmental Variation – Deafness Case study

NCEA case study

Q: One of the parents is a teacher who developed deafness last year as a result of having noisy classes.
Discuss the likelihood of this type of deafness being inherited by the new baby.

A: The parent / teacher became deaf because of loud noises related to teaching. Deafness was caused by 'environment', not genetics. **Only genetic characteristics can be inherited**, not those acquired as a result of environment. It is unlikely any of her children will be born deaf, as it appears the deafness was caused by environment, not genetics. However, we cannot determine whether they will be deaf at any stage in their life, as deafness can be work related and it depends on the job they have later in life.

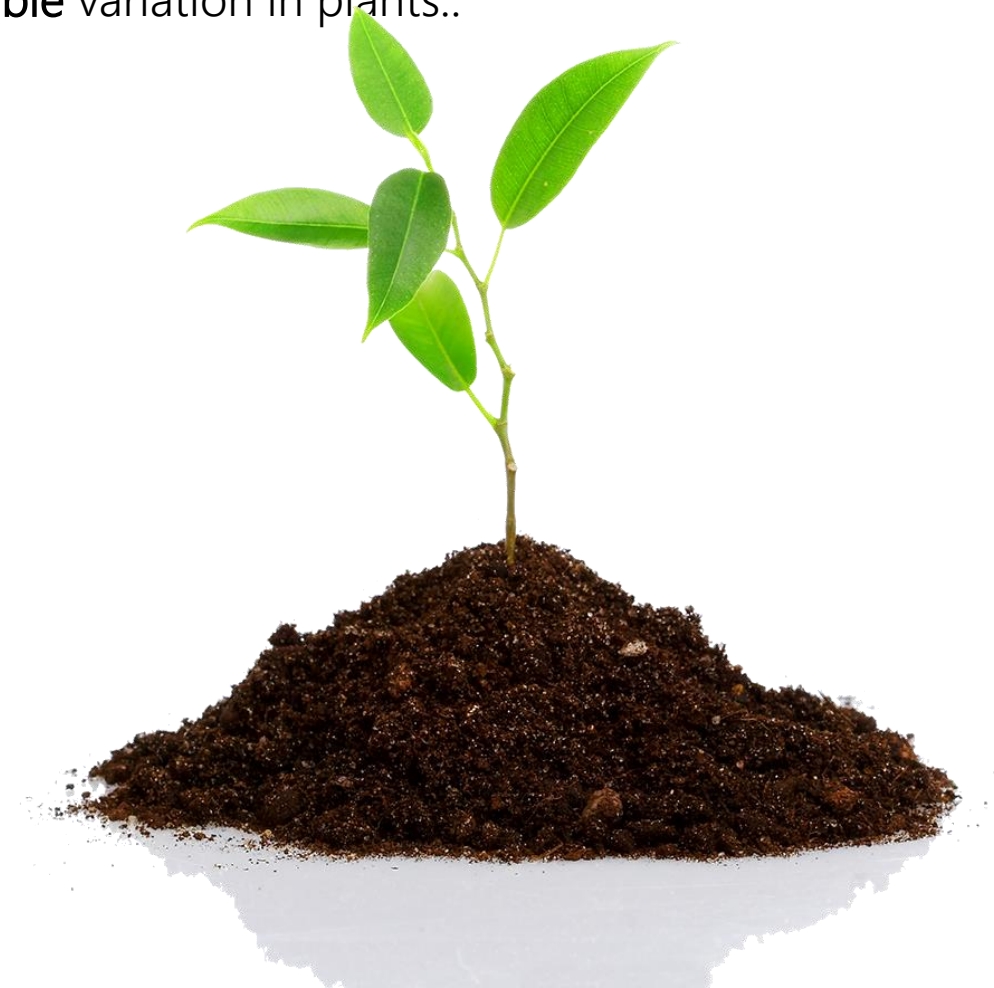
Genetics determines the characteristics you will be born with, but environment then affects these characteristics once you are born.

NCEA 2014 inheritable or non-inheritable variation - Plants

Merit Question

Question 1c: Variation within a species can be inheritable or non-inheritable.

(i) Give two examples of environmental factors that can lead to **non-inheritable** variation in plants..



Give TWO environmental factors (water / light / nutrients / wind / disease / pests etc) and link them to how they can effect the phenotype

NCEA 2015 inheritable or non-inheritable variation – disease in plants

Merit Question

Question 3a: The photograph below shows a large number of plants that are all the same species. The yellow-brown colour in some of the plants has been caused by a disease. The disease is present throughout the field, but affects only some plants. This is because of variation in the plants.
Explain why variation means not all the plants get the disease.

Answer 3a: There is variation in the plants shown in the photograph because the plants have different alleles / DNA / genes. Some alleles / DNA / genes result in a plant that is resistant to a disease but other alleles / DNA / genes result in a plant that is affected by a disease.

NCEA 2016 inheritable or non-inheritable variation – venus fly traps

Excellence Question

Question 3b: The Venus flytrap plants come in a number of different types, such as the "B-52" with a red leaf.
A teacher brought two identical plants to class and put them in different parts of the classroom. The Venus flytrap put near a window grew short leaves and the Venus flytrap in the shade grew long leaves.
Colour variation in the leaves of the Venus flytraps can be passed on to a plant's offspring, but the different leaf length cannot. **Explain why.** In your answer you should:
•define inheritable and non-inheritable variation
•explain what causes inheritable and non-inheritable variations.

Inheritable variation can be passed on to offspring and 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.

Lack of light has caused the fly trap in the shade to grow longer leaves. This is not due to a change in the DNA, and so cannot be passed on. The red colouration is due to DNA differences, and so can be passed on – as long as the DNA in the gametes is also affected.

Merit Question

NCEA 2017 Inheritable or non-inheritable variation – Black Panthers

Question 1b: Leopards in the wild commonly have scars, especially around their faces. Explain why the leopard cubs can be born with black coats but not with scars.

http://www.nzqa.govt.nz

http://www.wilderness-safaris.com/media/blog/camp-news/chitabe-leopard-identikits/copy-of-01-mosadi-mogolo-web.jpg

Genetics determines the characteristics you will be born with, but environment then affects these characteristics once you are born.

Inheritable variation can be passed on to offspring and 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. The black colouration of a leopards coat is due to DNA differences, and so can be passed on – as long as the DNA in the gametes is also affected.

Injury or fighting at some stage in a leopards life has caused the scars to form. This is not due to a change in the DNA, and so cannot be passed on because it is a non-inheritable variation Black colour is a change in the DNA, and so is passed on from parents to offspring through the gametes. Scars affect areas of the leopard's body, but not the DNA or the gametes, so cannot be passed on to offspring.

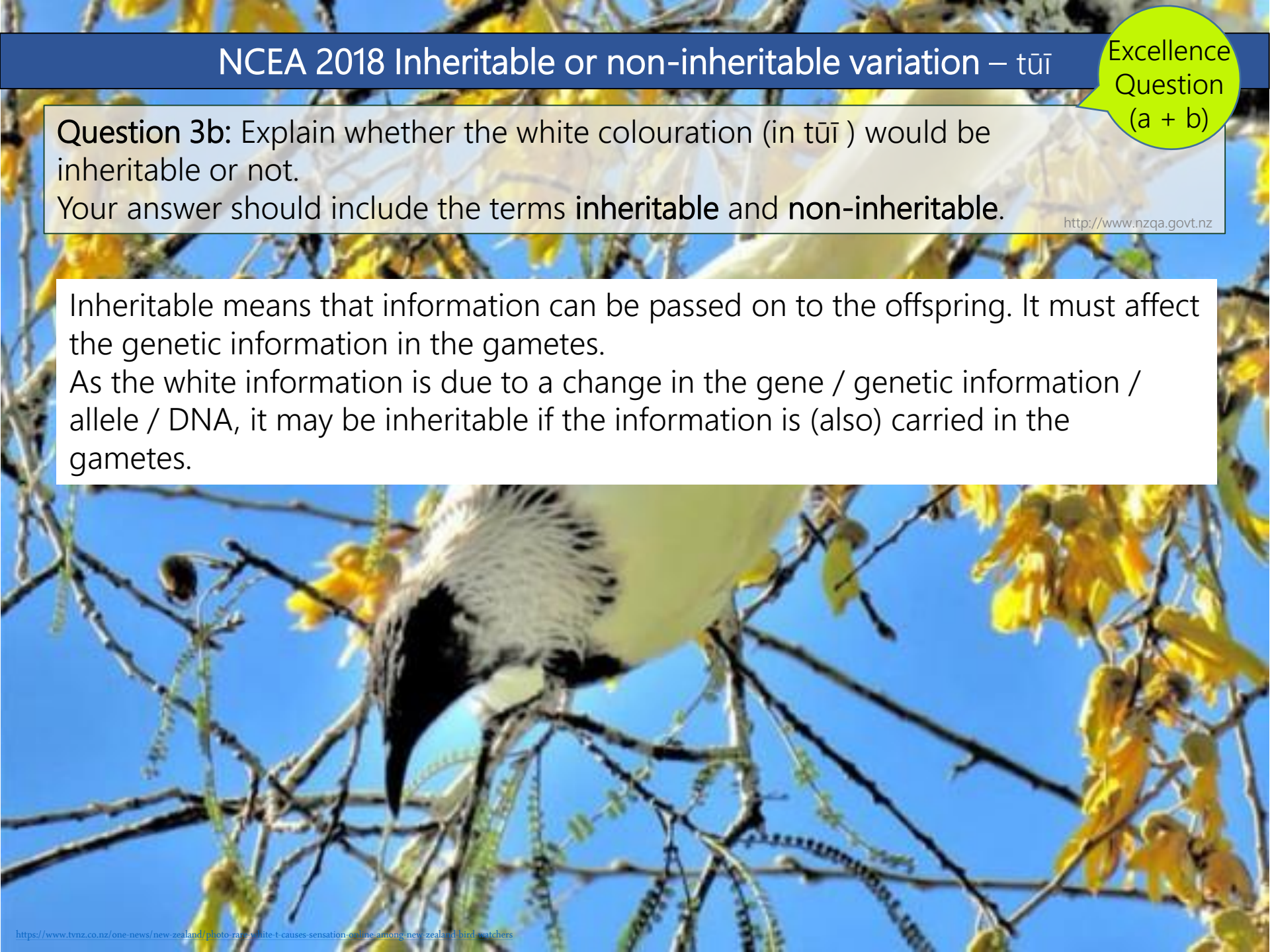
NCEA 2018 Inheritable or non-inheritable variation – tūī

Excellence Question (a + b)

Question 3b: Explain whether the white colouration (in tūī) would be inheritable or not.
Your answer should include the terms **inheritable** and **non-inheritable**.

http://www.nzqa.govt.nz

Inheritable means that information can be passed on to the offspring. It must affect the genetic information in the gametes.
As the white information is due to a change in the gene / genetic information / allele / DNA, it may be inheritable if the information is (also) carried in the gametes.



https://www.tvnz.co.nz/one-news/new-zealand/photo-rare-white-t-causes-sensation-online-among-nzs-bird-watchers

Continuous and discontinuous variation

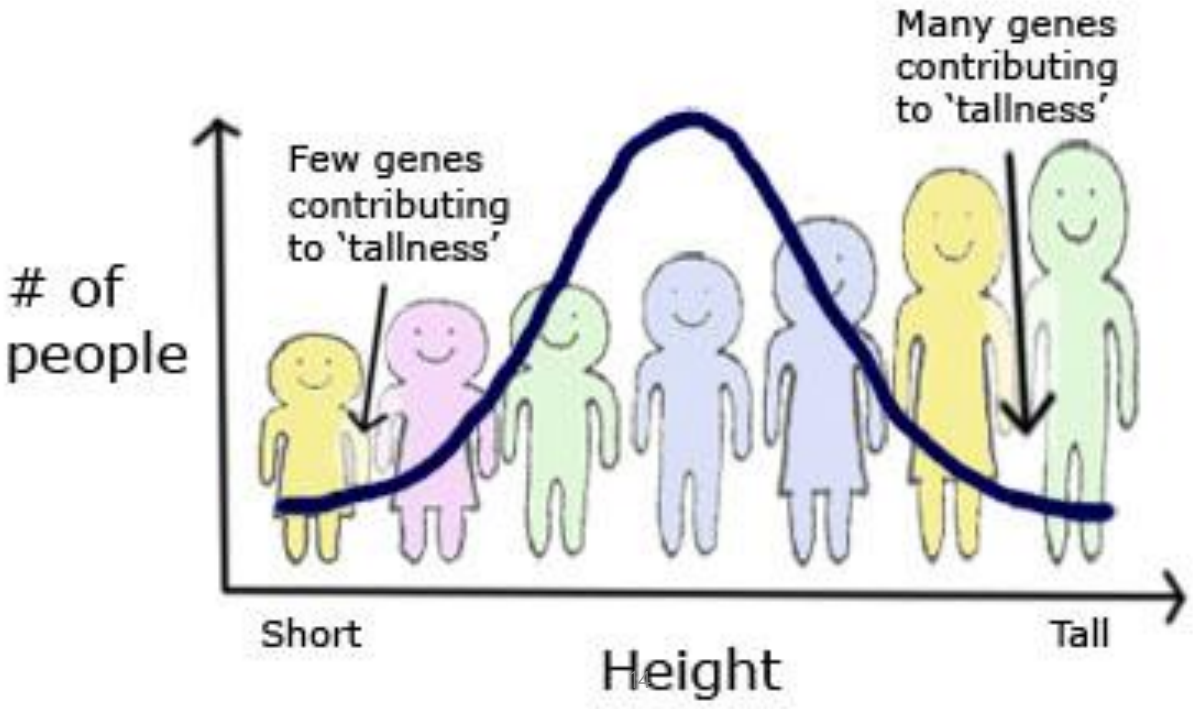
Inherited variation of a trait in an individual can be **continuous** such as tallness where height can be either very tall or very short as well as any height in between. Offspring will most often show height half way between the two parents as alleles inherited from both parents have a combined effect.

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. Traits such as these are either dominant or recessive.

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

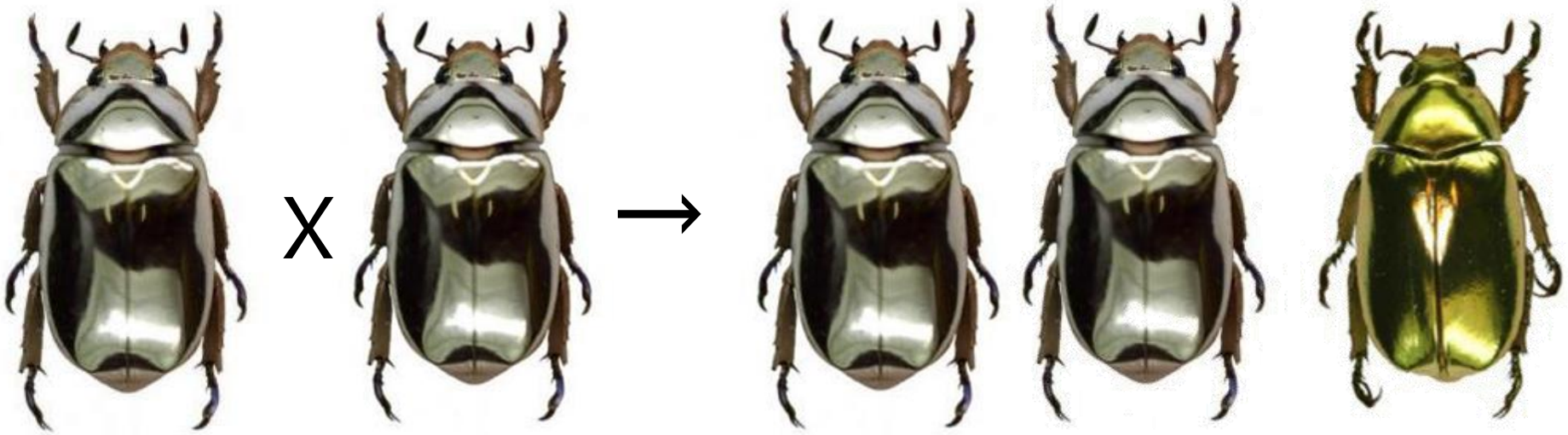
Meiosis (independent assortment and crossing over)

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.

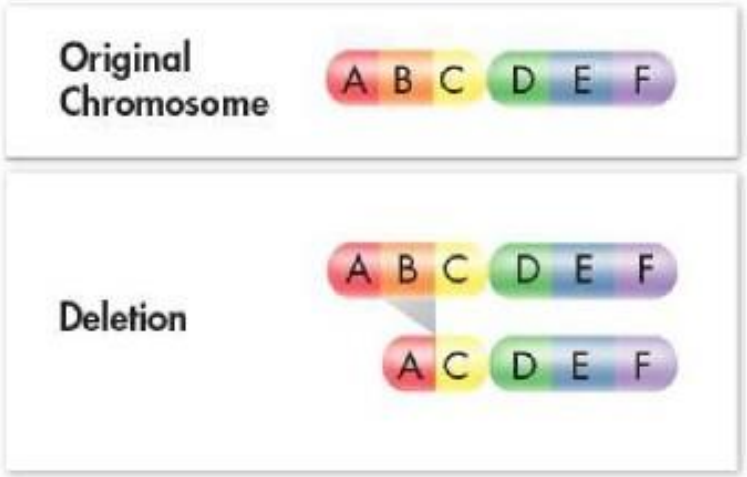


Mutations are caused by a random change in the sequence of bases in the DNA.

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).

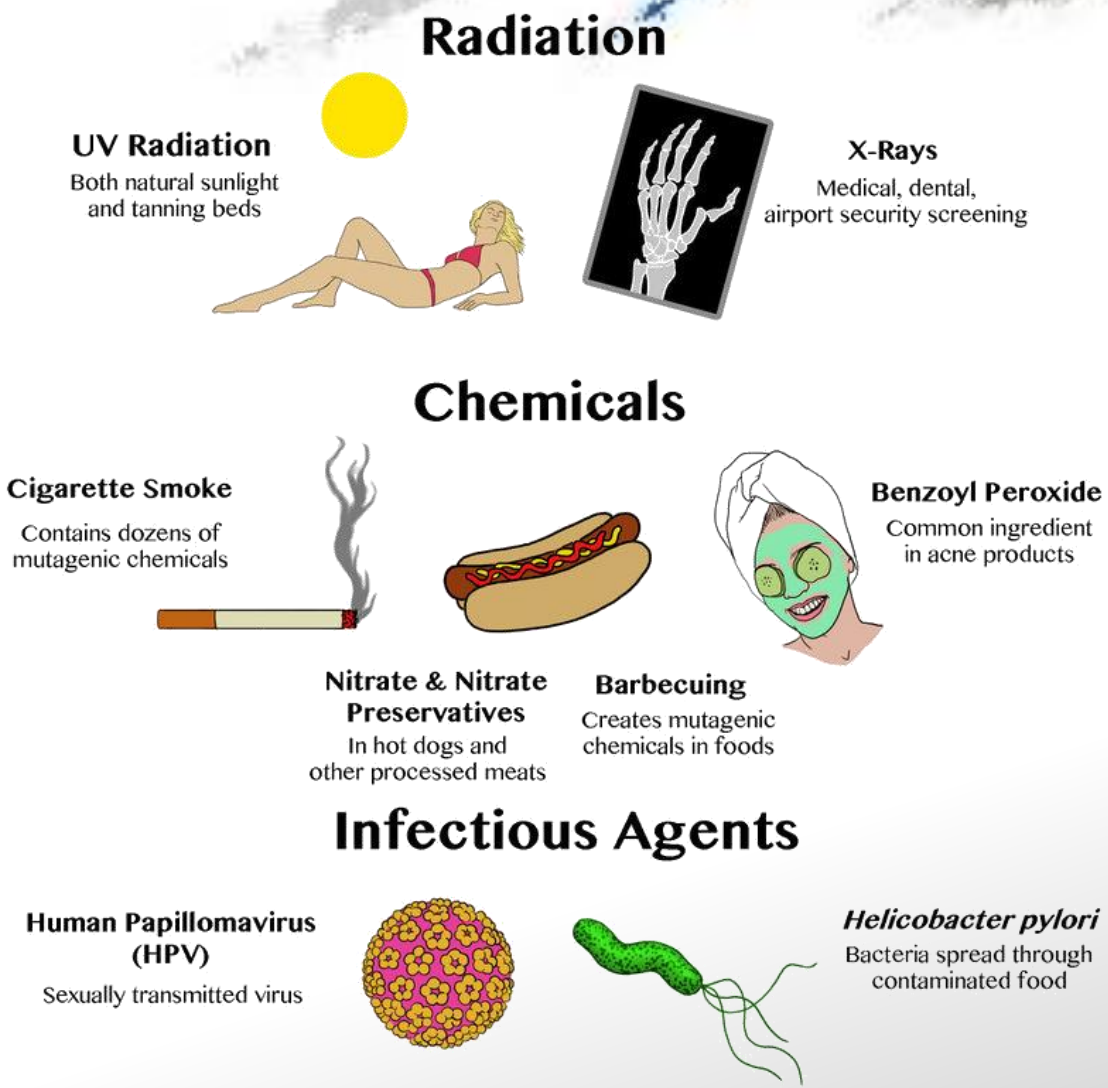
Mutations that occur in an adult's body cells (somatic cells) **will not be inherited** by offspring.



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.

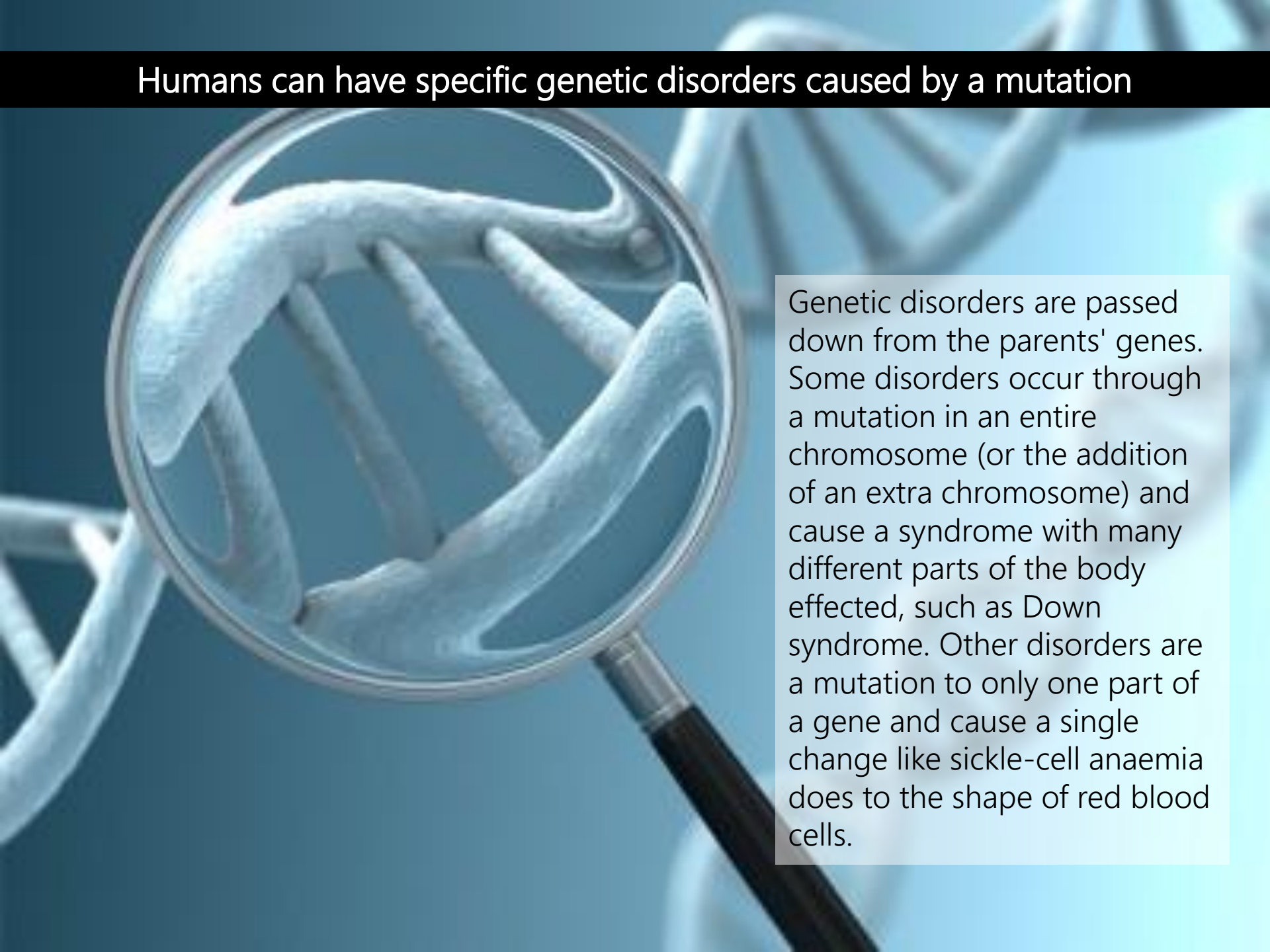
A mutagen is an agent that causes genetic mutation.

extra info



Inheritable Genetic disorders in humans are caused by one or more mutations in the genome (full set of genes), and is present from birth. Most genetic disorders are very rare. Mutations can be caused by random mistakes during DNA replication and meiosis or by environmental effects like chemical or radiation exposure during meiosis.

Humans can have specific genetic disorders caused by a mutation

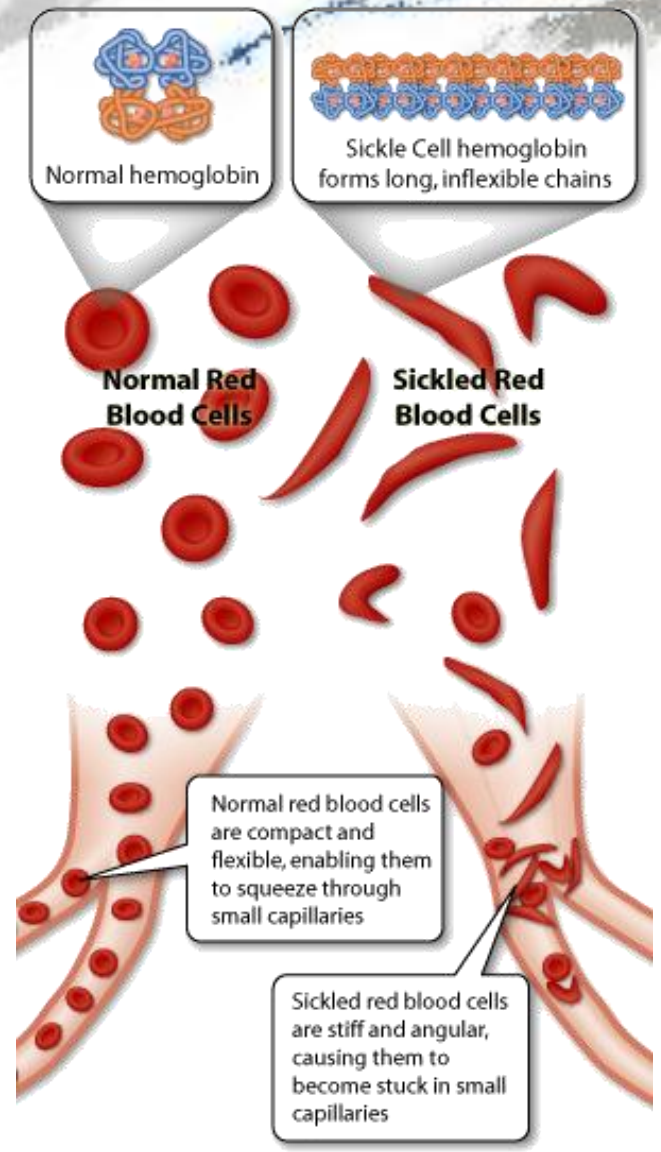


Genetic disorders are passed down from the parents' genes. Some disorders occur through a mutation in an entire chromosome (or the addition of an extra chromosome) and cause a syndrome with many different parts of the body effected, such as Down syndrome. Other disorders are a mutation to only one part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

Humans can have specific genetic disorders caused by a mutation during meiosis - EXAMPLES

extra info

Most disorders are recessive and require both parents to carry a copy of the mutation to show up in the offspring.
Some types of recessive gene disorders confer an advantage in certain conditions when only one copy of the gene is present, such as one copy of sickle-cell anaemia mutation gives resistance against malaria – a common disease in tropical countries.

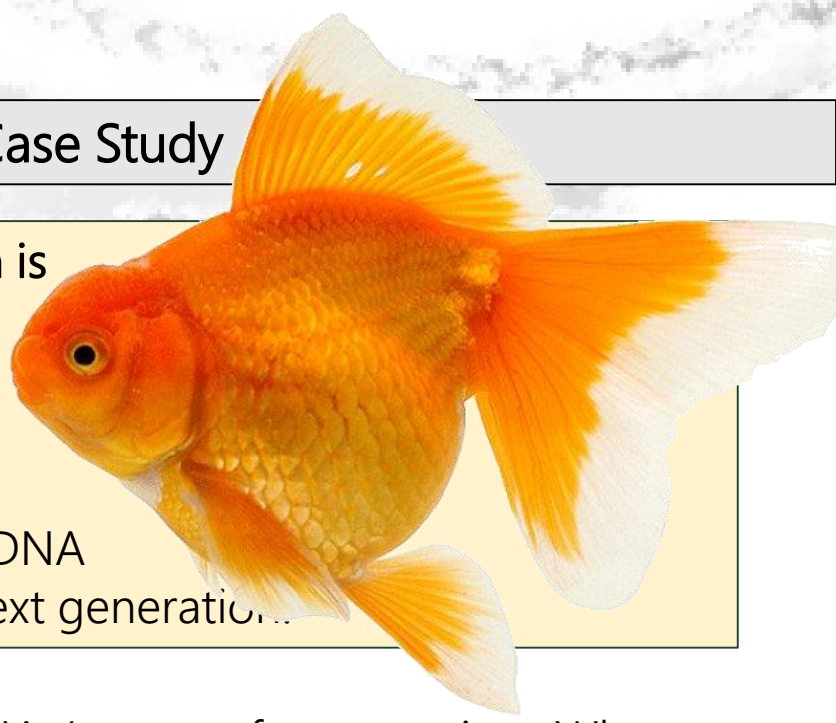


Humans can also have mutations occurring in either their X or Y chromosome (sex chromosomes) and therefore only passed on to Male offspring - if on the Y, or to female offspring – if on the X and is recessive.
If the mutation is recessive and on the X chromosome a male parent will only be a carrier.
This are called sex-linked disorders. Haemophila is an example and carried on the X chromosomes. Males without an extra X chromosome (a healthy chromosome to "block") show the mutation

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.

Mutations - NCEA Case Study



Q: One process that produces genetic variation is mutation. Explain what mutations are and how they contribute to genetic variation.

In your answer you should include:

- what a mutation is
- the effect of mutations on genes, alleles and DNA
- whether all mutations are passed on to the next generation.

A mutation is a change in genetic material / DNA / genes of an organism. When a mutation occurs, the base sequence of the gene changes; this results in completely new alleles. If mutations occur in the **gametes**, these new alleles have the possibility of being **passed on to offspring**.

If mutation occurs in **body cells, only the one individual will show variation** – will not be passed on to their offspring.

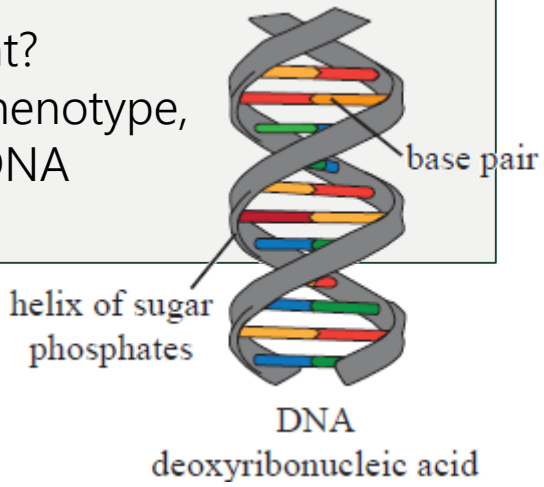
Mutations are more often than not harmful if they occur in part of the DNA that codes for traits. Individuals born with mutations will often die before they pass the mutant allele on.

Mutations do not always result in variation, but when they do, the variation is often in the form of entirely new alleles. If the new allele is beneficial, and increases survival and production of offspring, it is often spread quite quickly.

Excellence Question

NCEA 2017 Mutations – Black Panthers

Question 1a: Some leopards or jaguars have a **mutation** causing them to have a black coat. These are known as "black panthers".
(a) How can this **mutation** cause the coat colour to be different?
In your answer you should use the terms DNA, gene, allele, phenotype, and mutation to explain how this colour change occurs. The DNA diagram beside may help you. http://www.nzqa.govt.nz



DNA
deoxyribonucleic acid

DNA carries genetic information as a base code. A **gene** is a section of DNA that codes for 1 trait – in this case colouration.
A **mutation** is a change in the DNA base code, which affects the way a gene is expressed. In this case, a mutation in the colouration gene
could produce a new **allele** (form of a gene) – black. This is a new **phenotype** – the physical expression of the gene.

https://pixabay.com/en/panter-leopard-black-spotted-359245/ (cc)

NCEA 2018 Mutations – tūī

Excellence Question (a + b)

Question 3a: Leucism is a genetic condition caused by a gene mutation that results in some (or all) of an animal being white.
(a) How could a change in a **gene** result in the **phenotype** of the white tūī shown above? Your answer should include the terms **DNA** and **allele**.

http://www.nzqa.govt.nz

A gene is a section of DNA that codes for a trait, e.g. feather colour.
A phenotype is the appearance of the gene / genotype / DNA information / alleles, e.g. white feathers.
A mutation can cause a change in the DNA (base code) for a gene. This results in a change in how the genetic information is read and can create a gene form (allele) / different protein, and so changes the phenotype. In this case, the white tūī would have a different base sequence to normal tūī.

http://mandyart.blogspot.com/2009/07/white-tui-albino-slug.html

A white tūī

https://www.flickr.com/photos/sidm/6557924841

A coloured tūī

NCEA 2019 Mutations – milk tolerance

Excellence Question (all)

Question 3b: Some adults can digest milk, but the majority 65% cannot.
The ability to digest milk as an adult is caused by a DNA mutation.
(b) What is a mutation?
(c) Explain how a mutation can give adults the ability to digest milk.
You should include the terms **DNA**, **gene**, **allele**, **phenotype**, and **mutation**.
(d) Explain how a mutation can be passed on to the next generation.

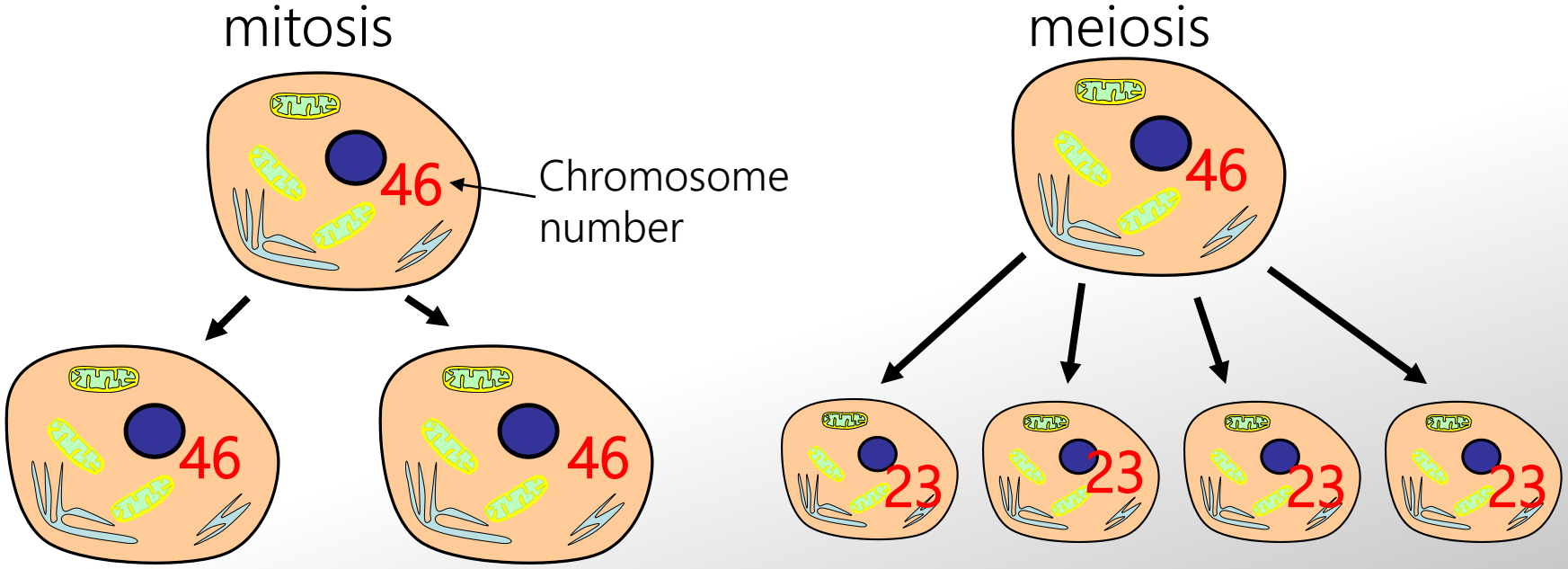
(b) A mutation is a change in the order of DNA bases that causes a new allele.
(c) DNA carries genetic information as a base code.
A gene is a section of DNA that codes for 1 trait / protein – in this case digesting milk.
An allele is a different form /version / expression of a gene.
A mutation is a change in the order of DNA bases that causes a new allele. The new allele codes for the phenotype 'ability to digest milk as an adult'.
(d) A mutation coding for the ability to digest milk as an adult can be passed down in the DNA from either parent when sperm and egg (gametes) fuse.

Mitosis and Meiosis

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

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.

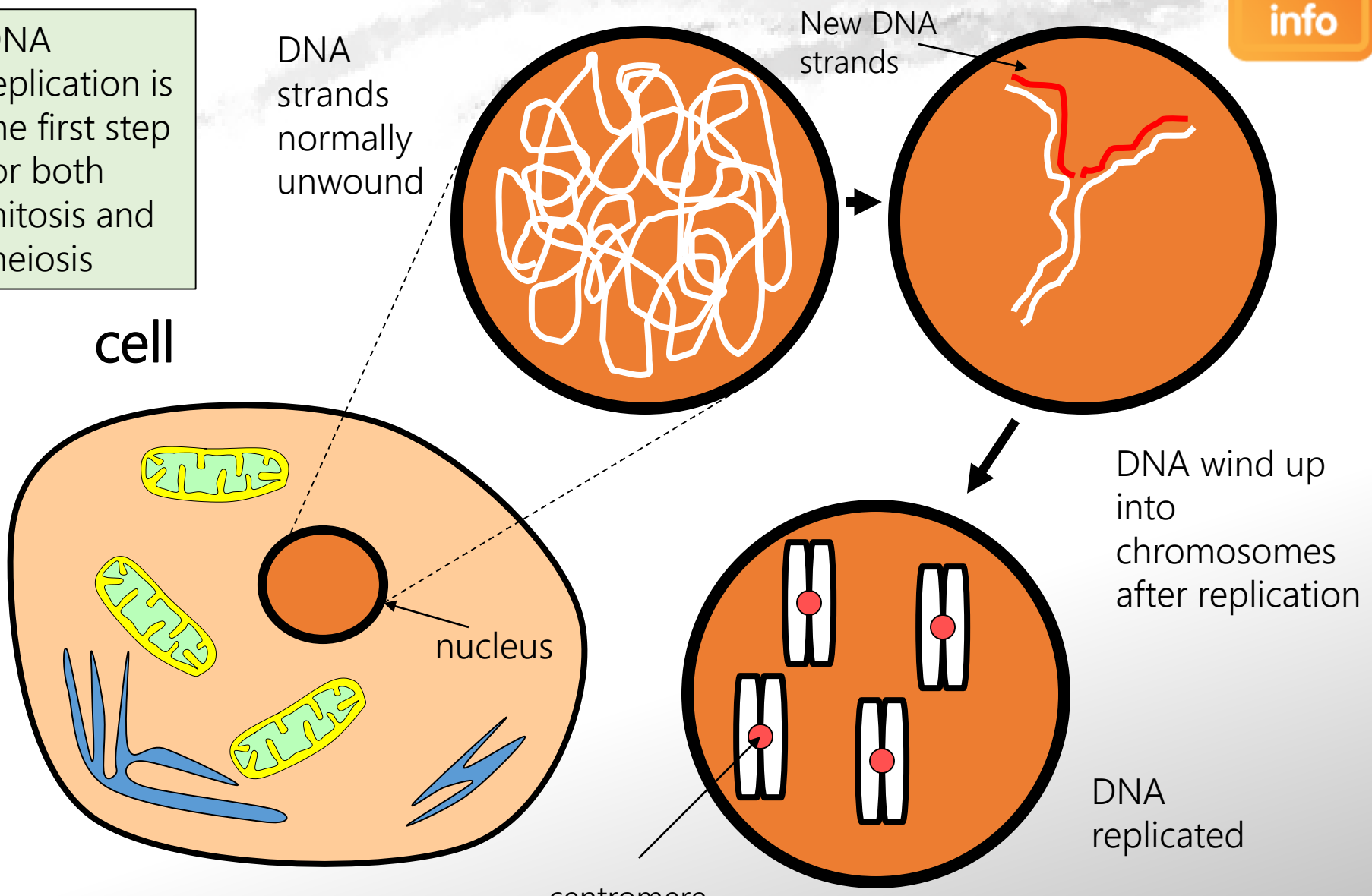


students are not required to provide the names of the stages of meiosis

DNA replication creates two identical copies of each chromosome

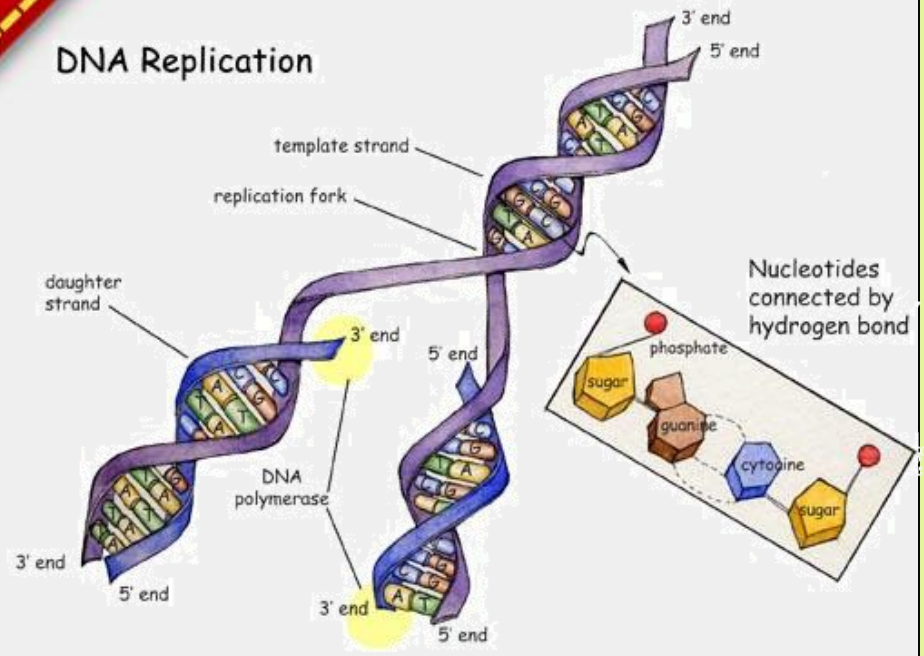
extra info

DNA replication is the first step for both mitosis and meiosis



Background Knowledge

DNA replication creates two identical copies of each chromosome



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.

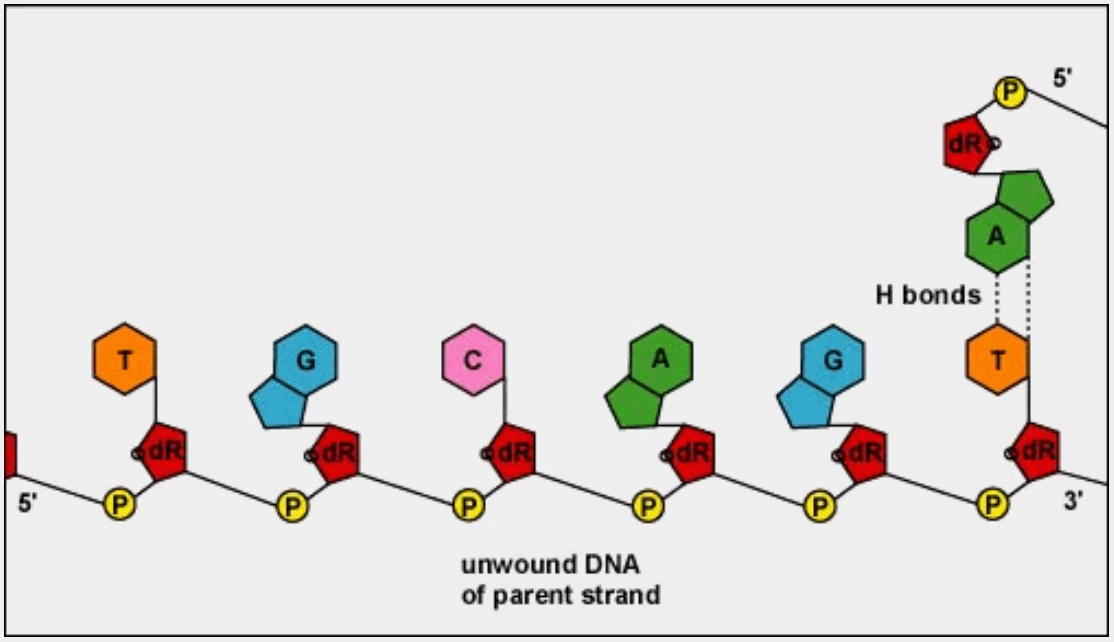
Each Chromosome unwinds and the two sides of the DNA chain separate (with assistance from un "unzipper" enzyme. New nucleotides (consisting of a sugar, phosphate and matching base) line up against each exposed base on the pulled apart ladder.

Eventually 2 new strands have form, with one original side and one newly formed side each.

Background Knowledge

DNA replication creates two identical copies of each chromosome

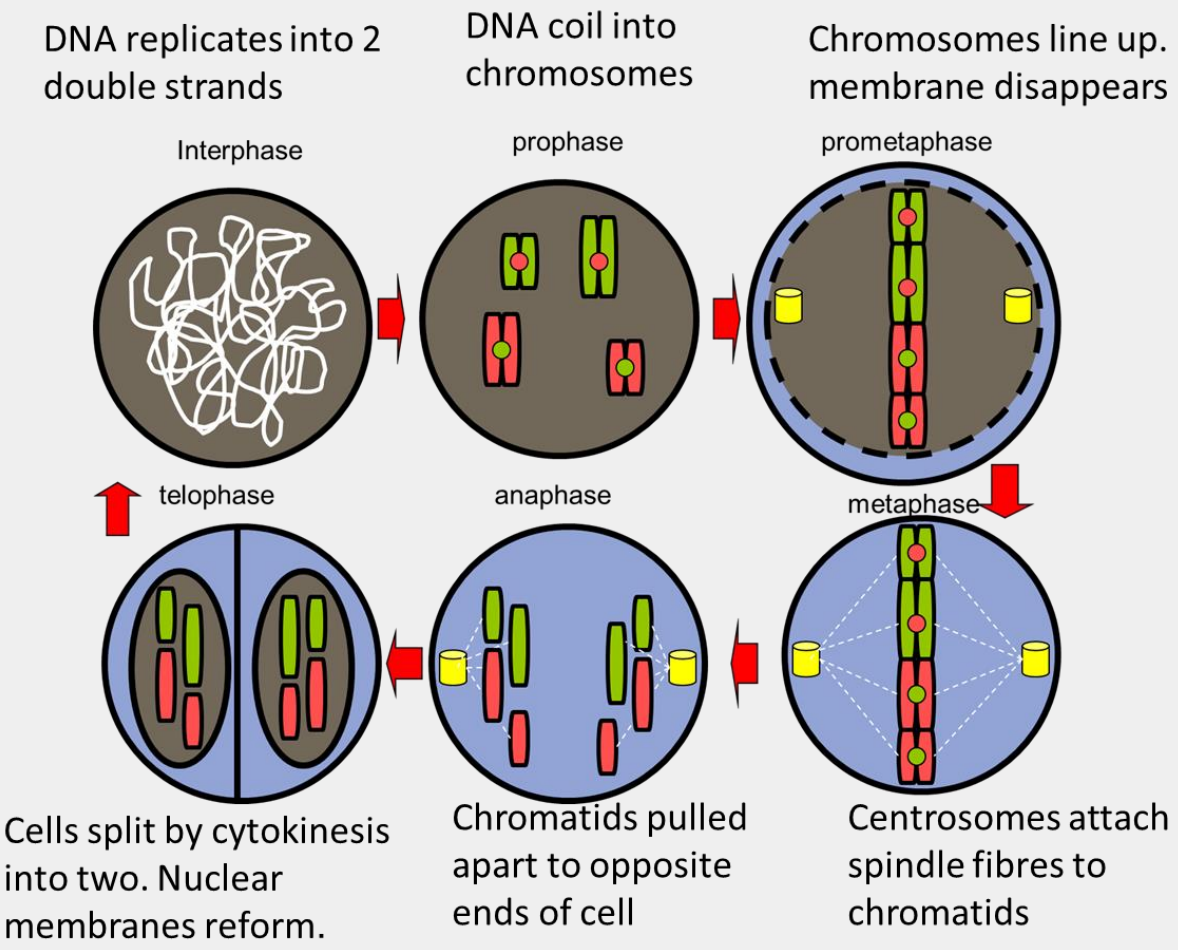
When the DNA "unzips" between the hydrogen bonding of the two sides of the ladder each side joins onto matching paired nucleotides that are free floating in the cytoplasm. Two copies of each DNA strand that make up a chromosome are now created, and they are held together with a centromere until each copy moves into a new cell.



Background Knowledge

Mitosis creates two identical cells

The focus for NCEA L1 is on Meiosis

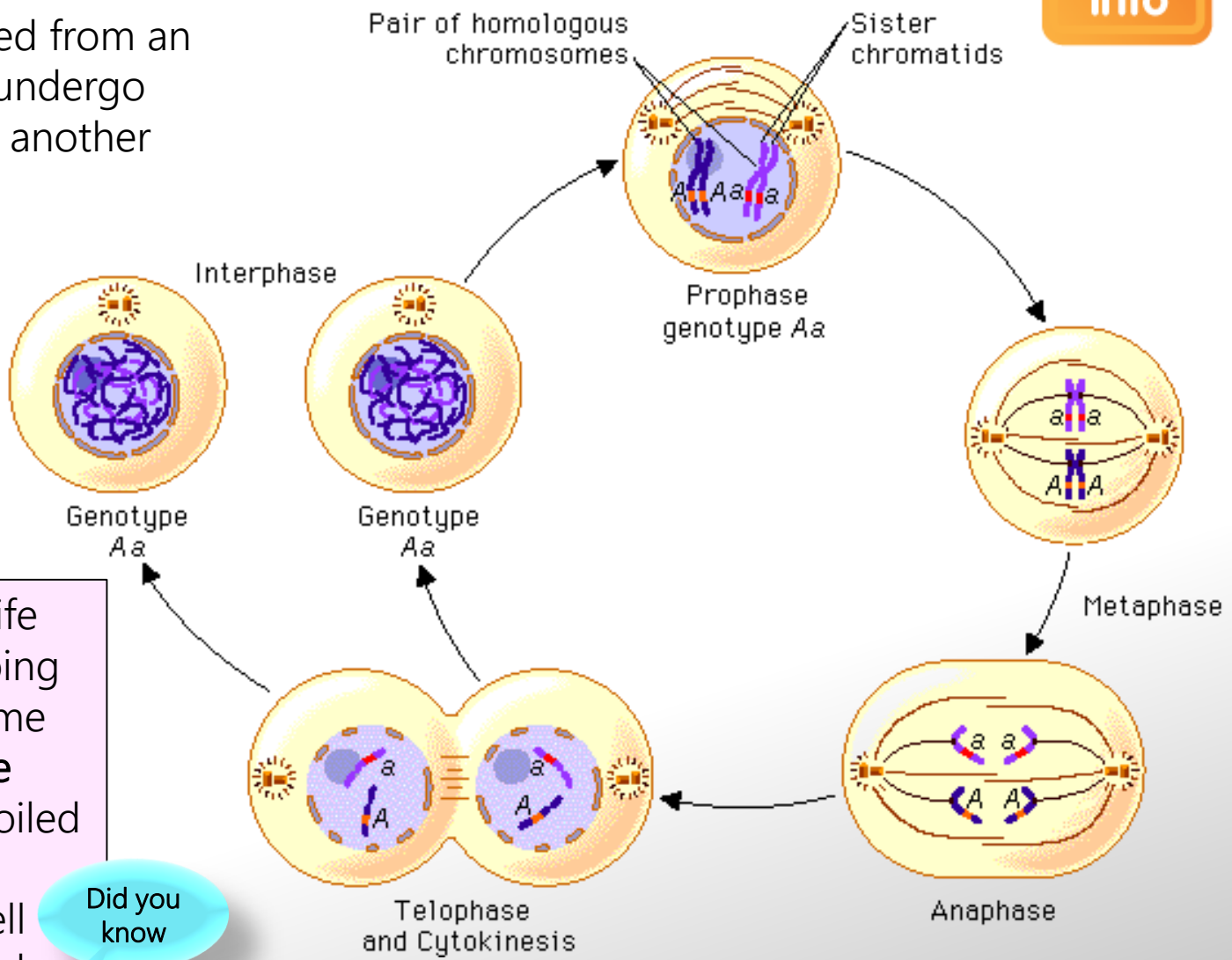


Mitosis creates two identical cells

extra info

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.

Mitosis is only included to compare with meiosis



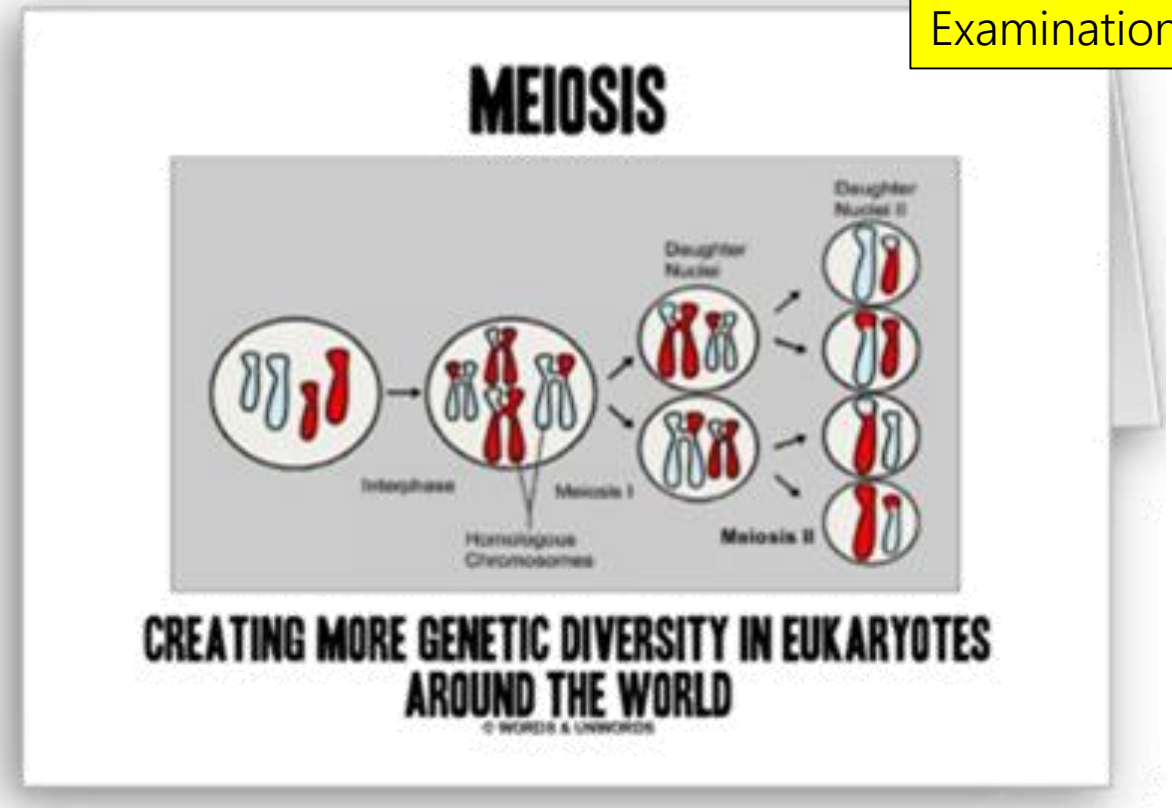
Only part of the cells life cycle is spent undergoing mitosis. Most of the time the cell is in **interphase** where the DNA is uncoiled and protein is being produced as well as cell processes being carried out.

Did you know

Meiosis creates gametes with variation

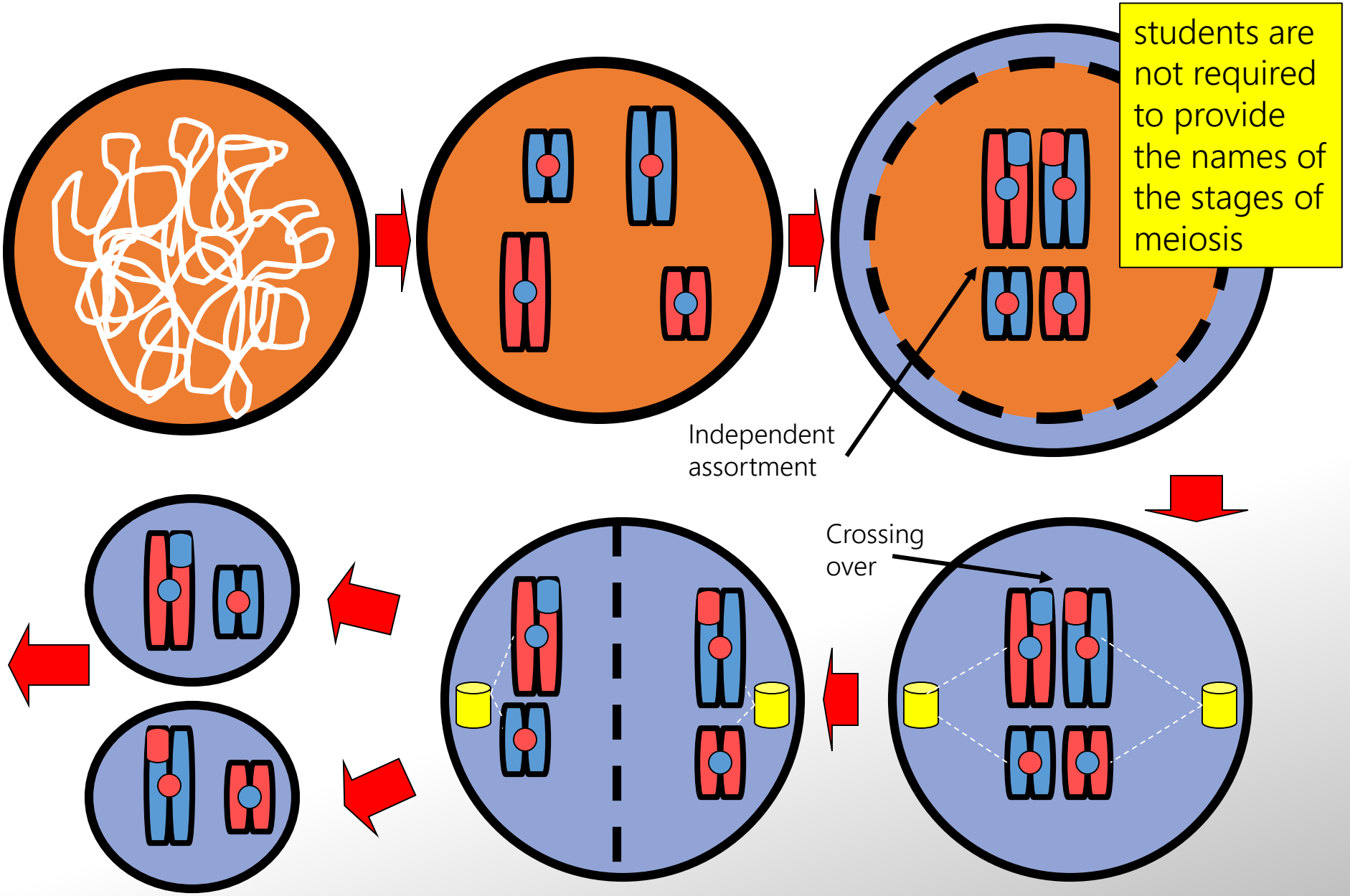
Sources of variation is a common question in Examinations

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).

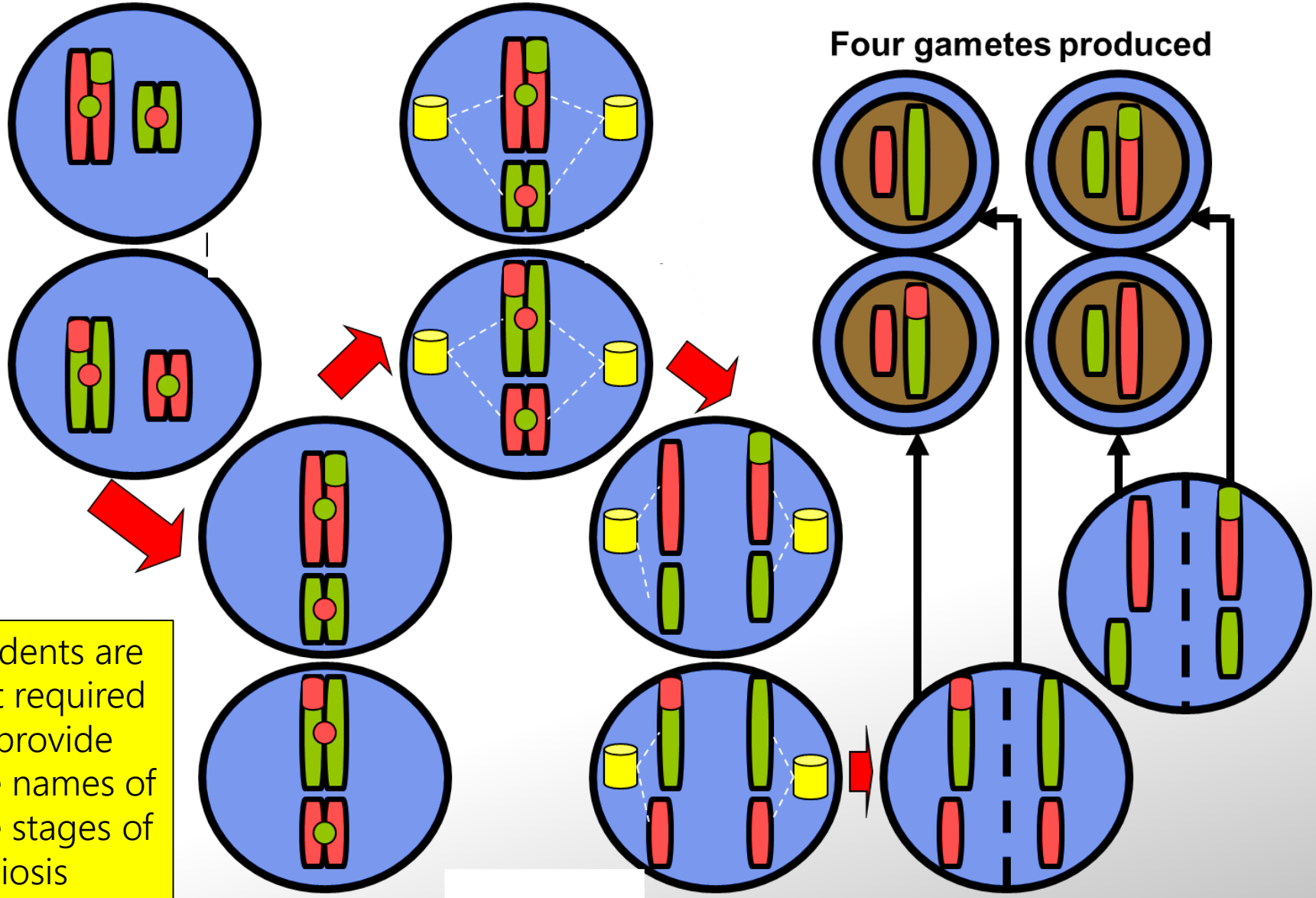


Secondly, portions from each homologous pair swap (called **crossing over**) creating different combinations of alleles in once identical copies. Another opportunity for variation occurs during **fertilisation** when any male gamete can combine with any female gamete randomly.

Meiosis creates gametes with variation – Stage one



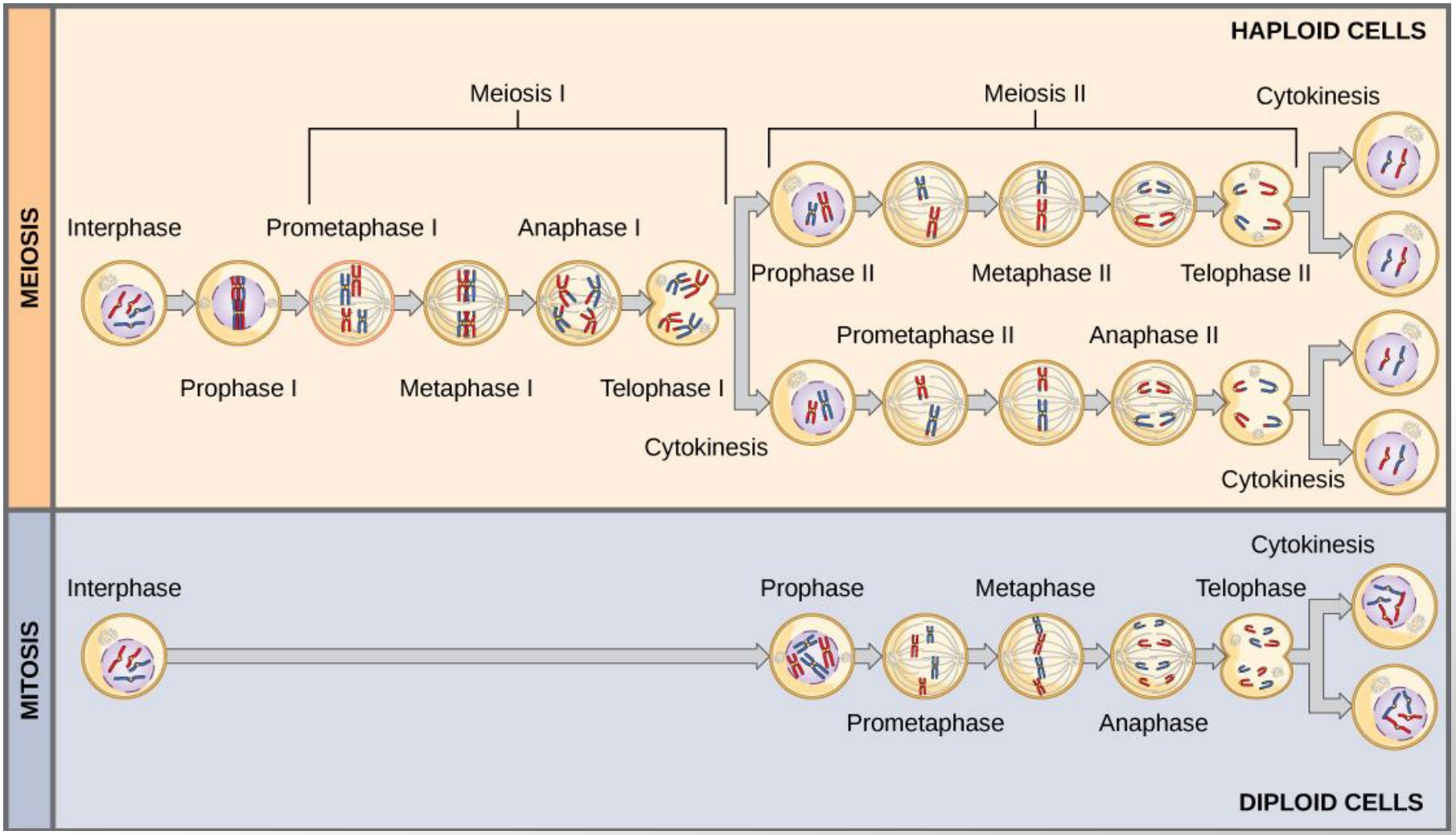
Meiosis creates gametes with variation – Stage two



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

Comparing mitosis and meiosis

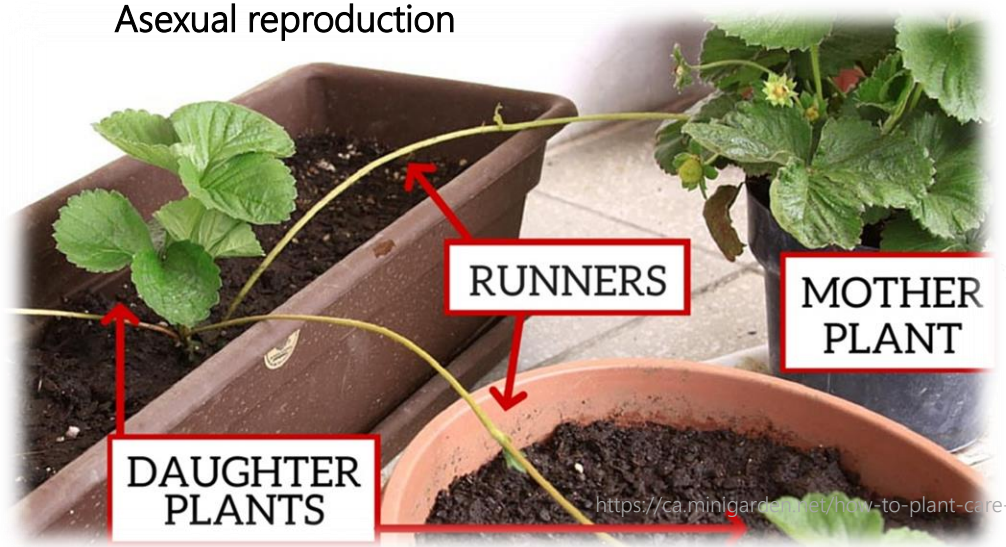
The main difference between the two processes is that **Mitosis** produces **identical cells** with the **full set of chromosomes** and **Meiosis** produces **gametes with variation** that only have a **half set of chromosomes**.



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.

Asexual reproduction



https://ca.minigarden.net/how-to-plant-care-for-strawberries/

Sexual reproduction

http://dognamesearch.com/how-long-are-dogs-pregnant-before-they-give-birth/

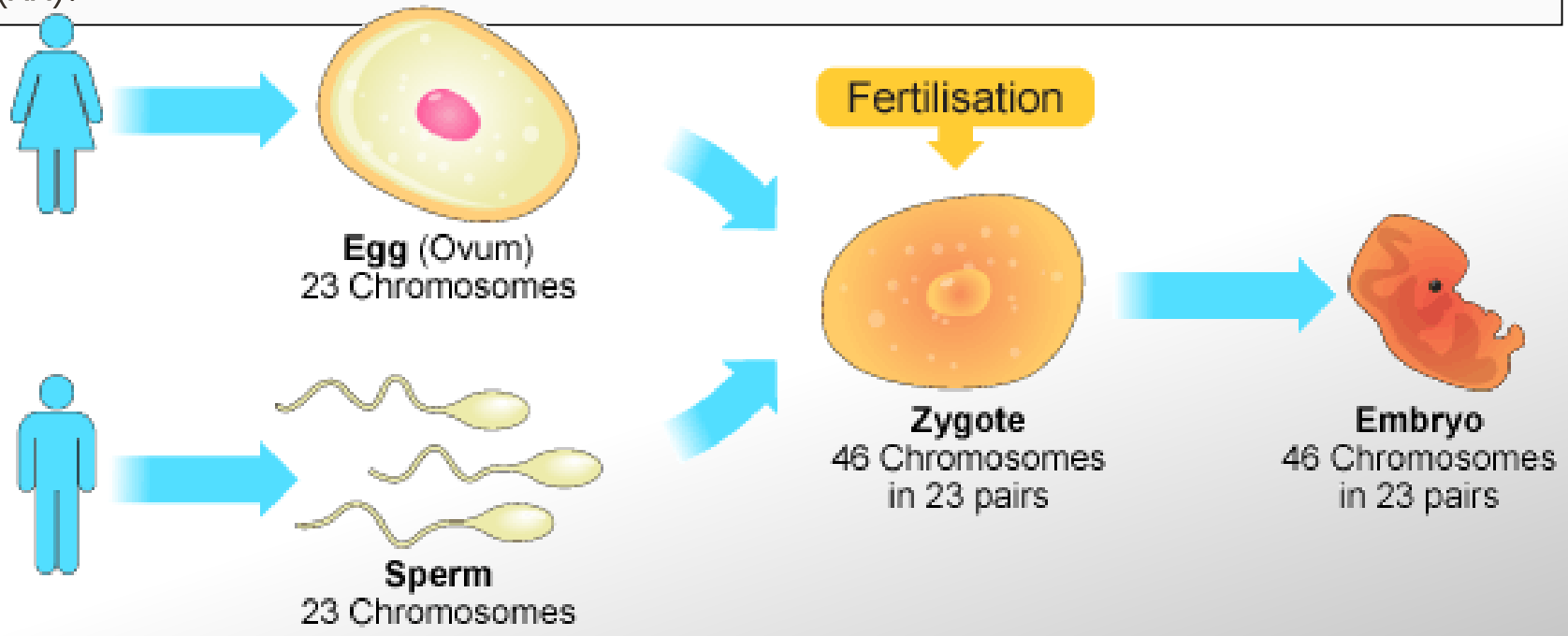
Sexual Reproduction

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 (e.g. sperm) fusing with a stationary female gamete (e.g. egg)

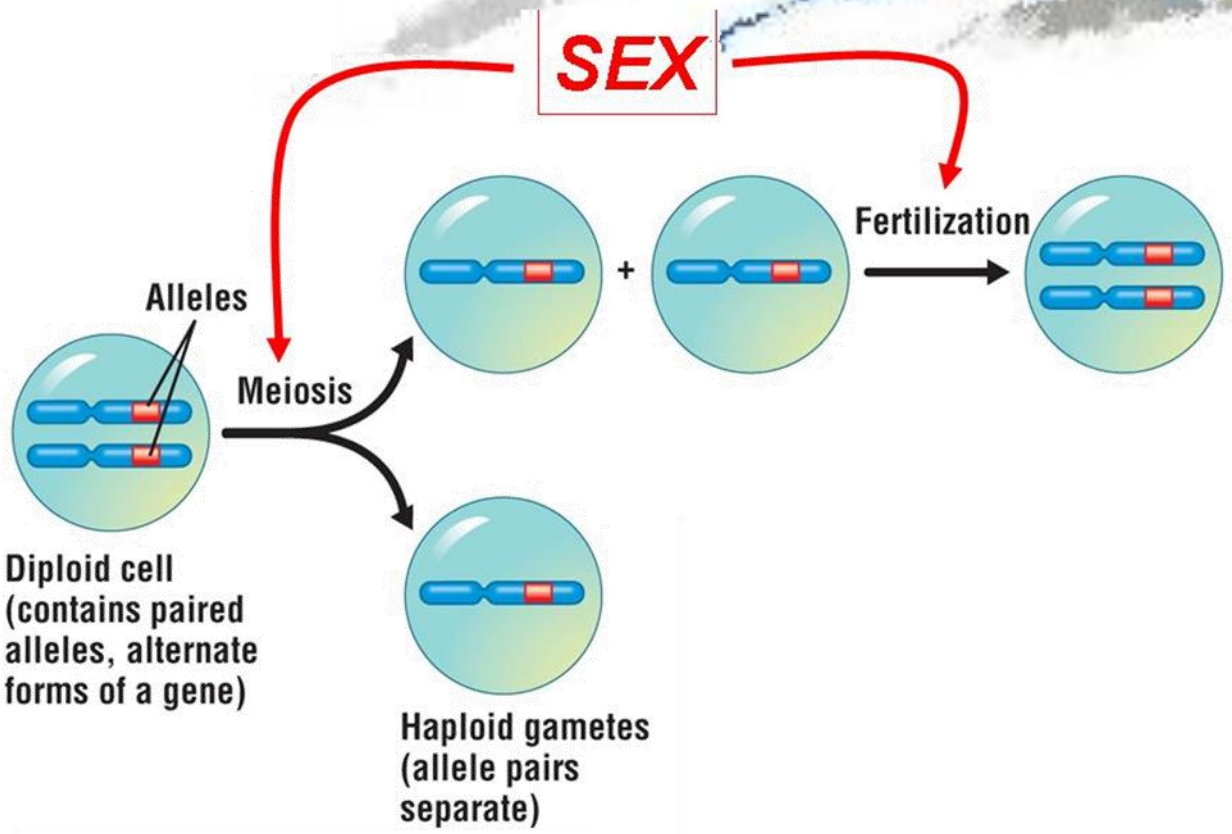
Both males and females only donate half of their chromosomes, one from each homologous pair, to form gametes through **meiosis**. (gametes = egg or sperm). When the chromosomes from the egg and sperm rejoin to form a **zygote** with the total number of chromosomes **fertilisation** has occurred. Whether 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

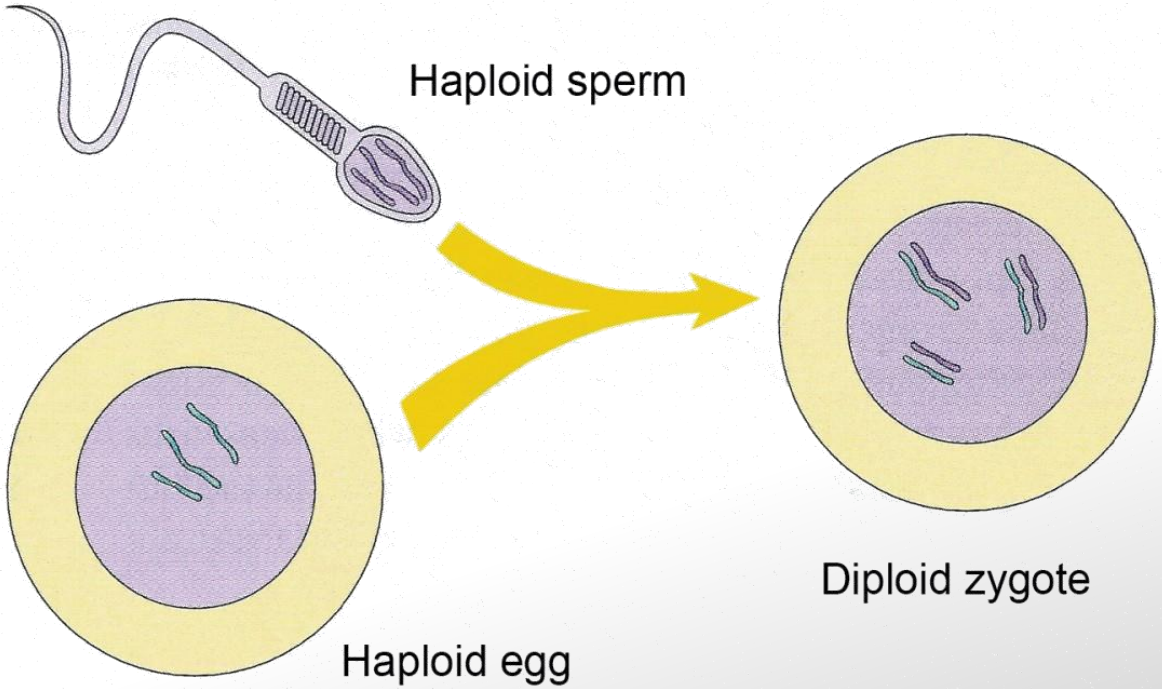


Genes are passed on from parents when the DNA in each parents gametes combine to form an embryo during fertilisation, which then develops into a baby. Variation occurs when each parents gametes are created – sperm in males and eggs in females – through a process of **Meiosis**.

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.

Haploid and Diploid

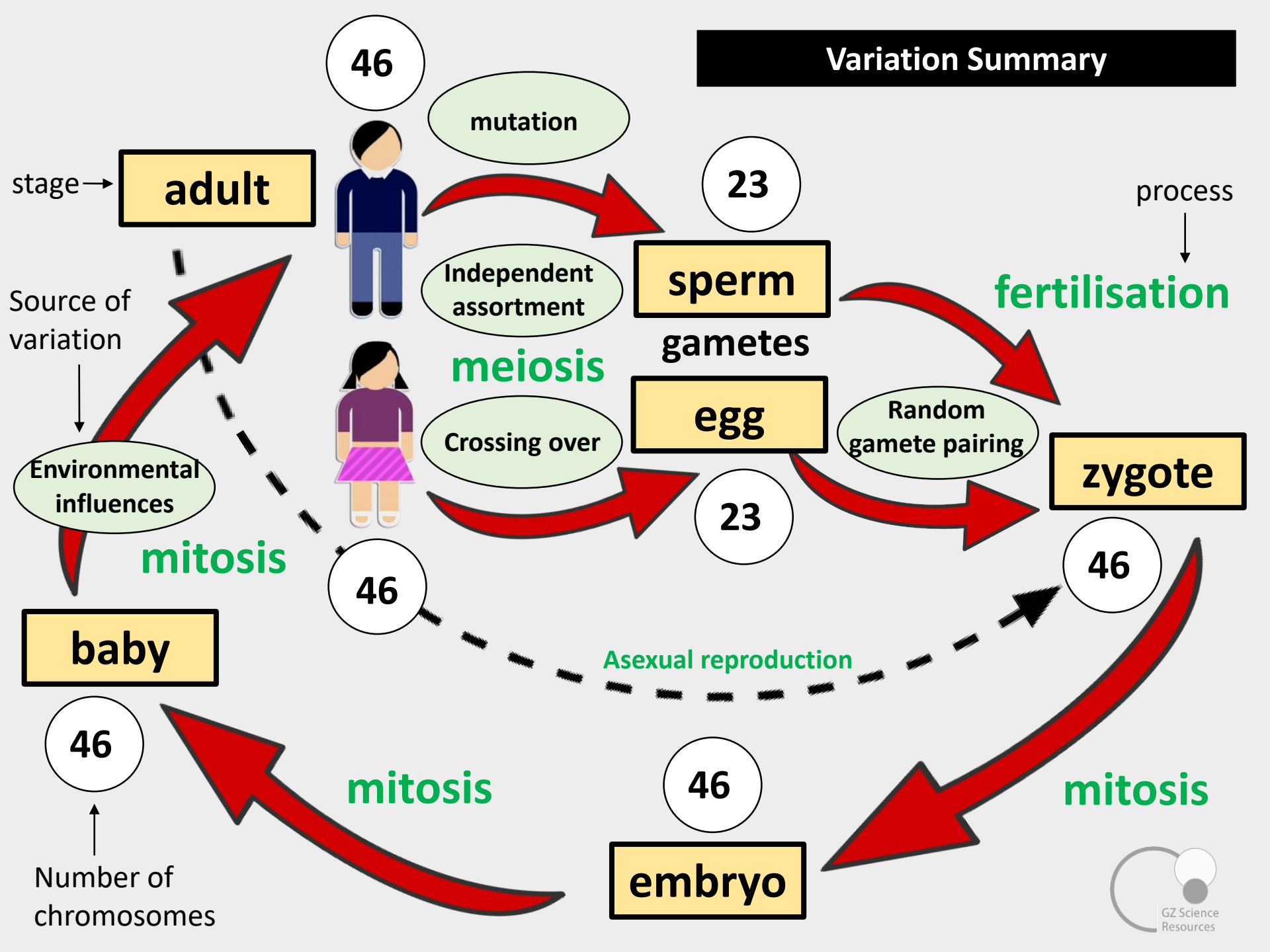
Gametes contain only one set of chromosomes and are known as **haploid** (or half). All other cells in an organism contain the usual two sets of chromosomes inherited from both parents and are known as **diploid** (2 or double).



extra info

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 sex
reproducing sp

Did you know


Variation Summary
46
mutation
stage
adult
23
process
Independent assortment
sperm
fertilisation
Source of variation
gametes
meiosis
egg
Crossing over
Random gamete pairing
Environmental influences
zygote
23
mitosis
46
46
baby
Asexual reproduction
46
mitosis
46
mitosis
Number of chromosomes
embryo
GZ Science Resources

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

extra info

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

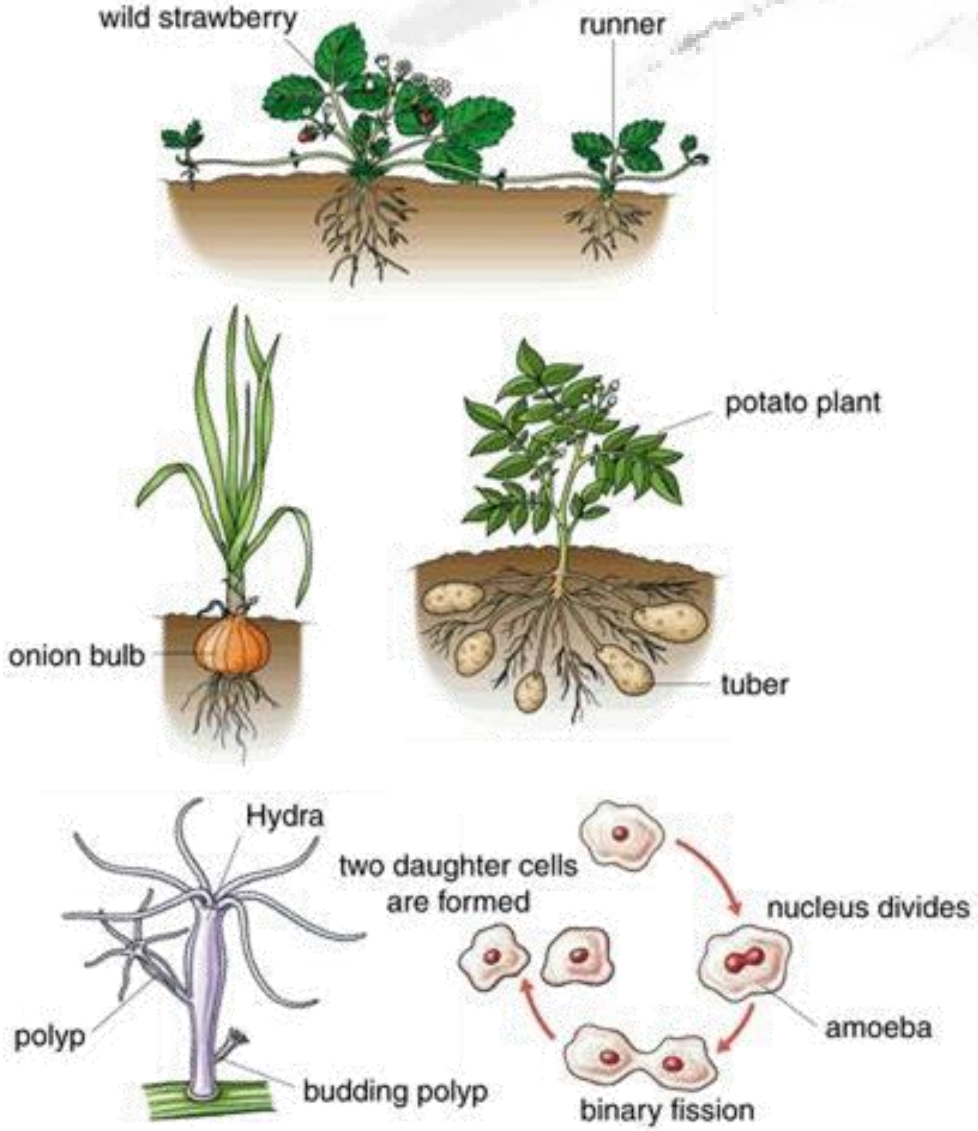
Asexual reproduction occurs when only a single individual passes on all its genes to the offspring. The offspring are genetically identical to the parent. Sexual reproduction occurs when two parents create offspring and pass only half their genes to the offspring. The offspring half a different/unique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

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.)

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. Another advantage is that if the species is well adapted to an environment then all of the identical offspring will be equally well adapted. 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.

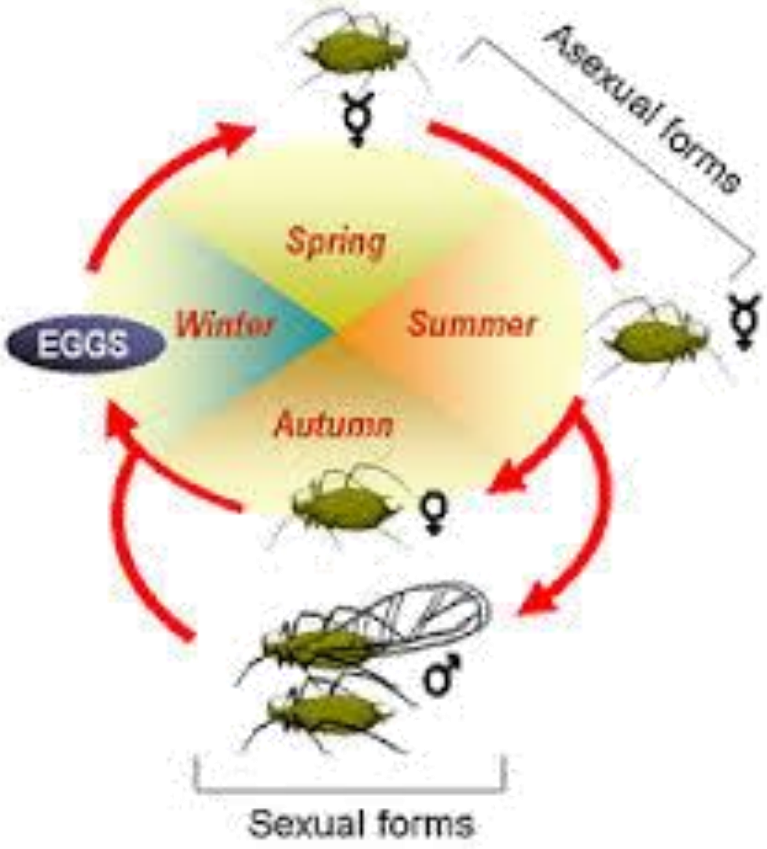
Summary of Advantages and disadvantages of **Asexual Reproduction**

Advantages	Disadvantages
Fast – do not have to spend time producing flowers or attracting mates	
No need to spend energy producing flowers or finding a mate	
No need to rely on pollinators/males	
Guaranteed success of producing offspring	
Can make numerous copies of plants through cuttings	Population overruns a food source quickly
All desirable traits are passed down	If parents have an undesirable trait then all offspring inherit it
All offspring are genetically identical and best suited to an environment if conditions remain stable	All offspring are identical so this creates vulnerability if the environment changes or pests/ diseases occur

Comparing Asexual Reproduction and Sexual reproduction

extra info

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 identical	Each individual offspring has a unique combination of genes
Variation is only created by rare mutation	Variation is created in each individual



Birds of Paradise - Sexual reproduction Case Study

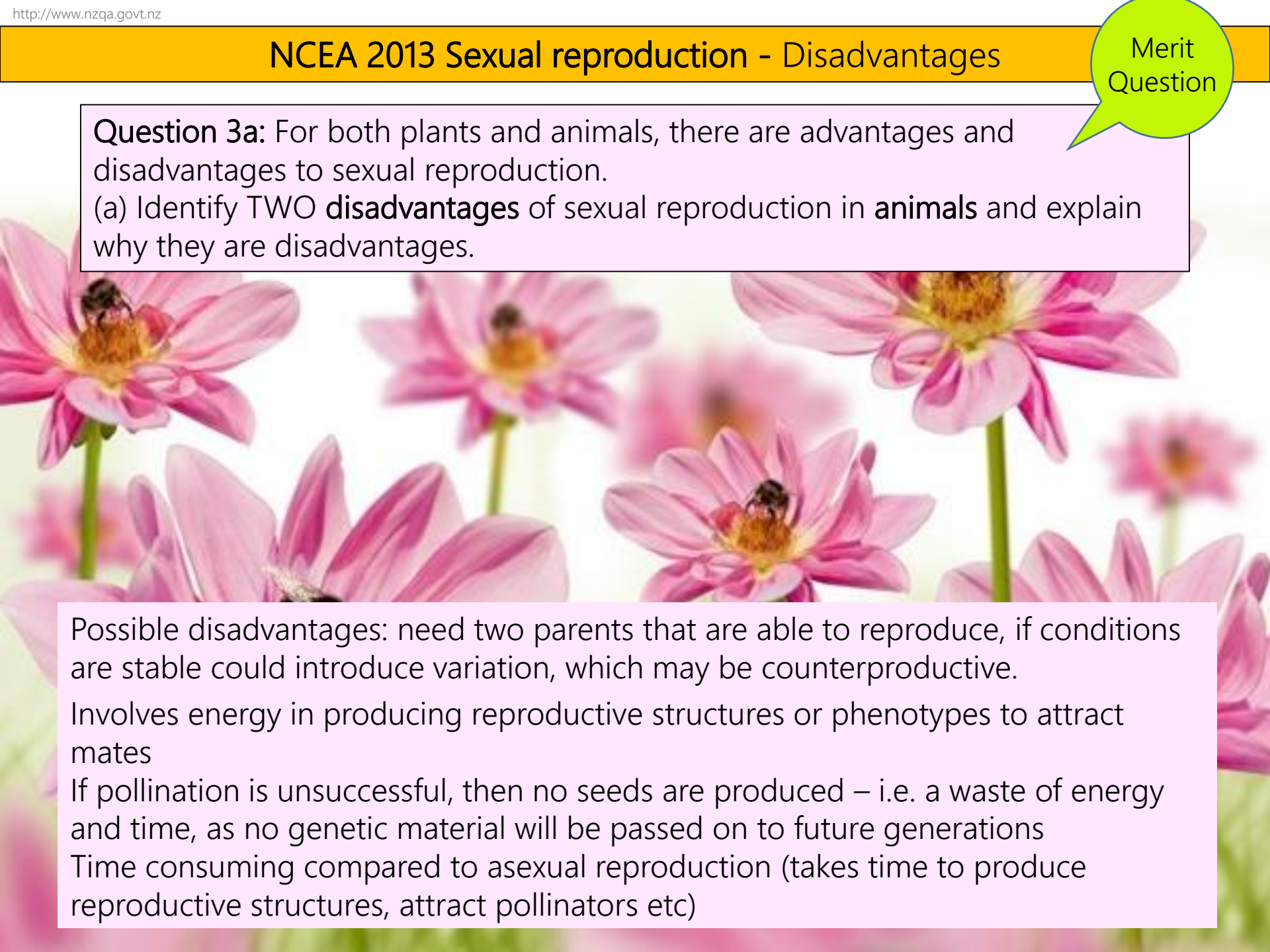
The Raggiana bird-of-paradise lives in Papua New Guinea. The male bird has colourful long feathers and competes for females in a lek where it displays its plumage along with many other males to a watching group of female birds. The female is a comparatively dull reddish-brown bird with no long tail feathers. The males with the longest, most colourful displays attract the females who then allow the males to mate and pass along their genes. Feather colour and length along with dance behaviour are controlled by alleles that are genetically inherited but variable in a population.

The advantages of sexual reproduction is that **variation occurs in the population**. Females can use this variation in feathers and dance to determine the health of the male and select the individual that will best carry their genes into the next generation. The disadvantage of this form of sexual reproduction is the **energy extended by the male to attract the female** and the lack of adaptation of the feathers for flight.

NCEA 2013 Sexual reproduction - Disadvantages

Merit Question

Question 3a: For both plants and animals, there are advantages and disadvantages to sexual reproduction.
(a) Identify TWO **disadvantages** of sexual reproduction in **animals** and explain why they are disadvantages.



Possible disadvantages: need two parents that are able to reproduce, if conditions are stable could introduce variation, which may be counterproductive.

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)

NCEA 2013 Sexual reproduction - Disadvantages

Merit Question

Question 3b: Explain how sexual reproduction contributes to variation in a population of **animals**.
In your answer you should refer to gametes, meiosis and fertilisation.

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.

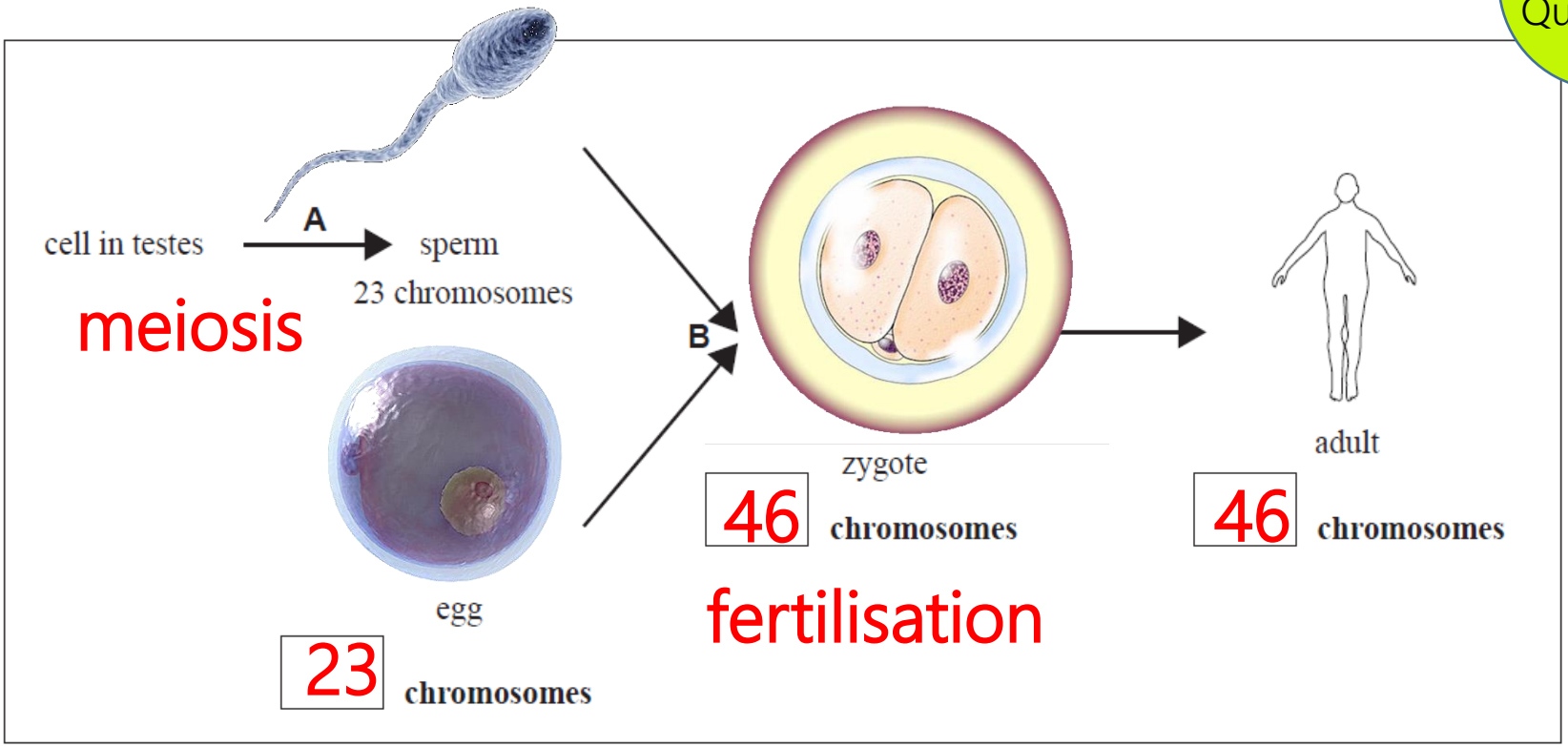
During fertilisation, the gametes combine and the resulting offspring will have two alleles – they may inherit two alleles the same, homozygous, and show that characteristic or they may inherit one of each allele, heterozygous in which case they will show the dominant allele in their phenotype.

NCEA 2014 Sexual reproduction - gametes

Achieved Question

Question 2a: The diagram below shows the relationship between gametes (sex cells), zygotes, and chromosome number in humans.
Name the processes represented by **A** and **B**:
Question 2b: Complete the diagram above by writing the numbers of chromosomes in the boxes.

Achieved Question



NCEA 2014 Sexual reproduction - gametes

Merit Question

Question 2c: Compare the chromosome number of the egg, sperm, zygote and adult, AND explain any differences and similarities in the numbers.

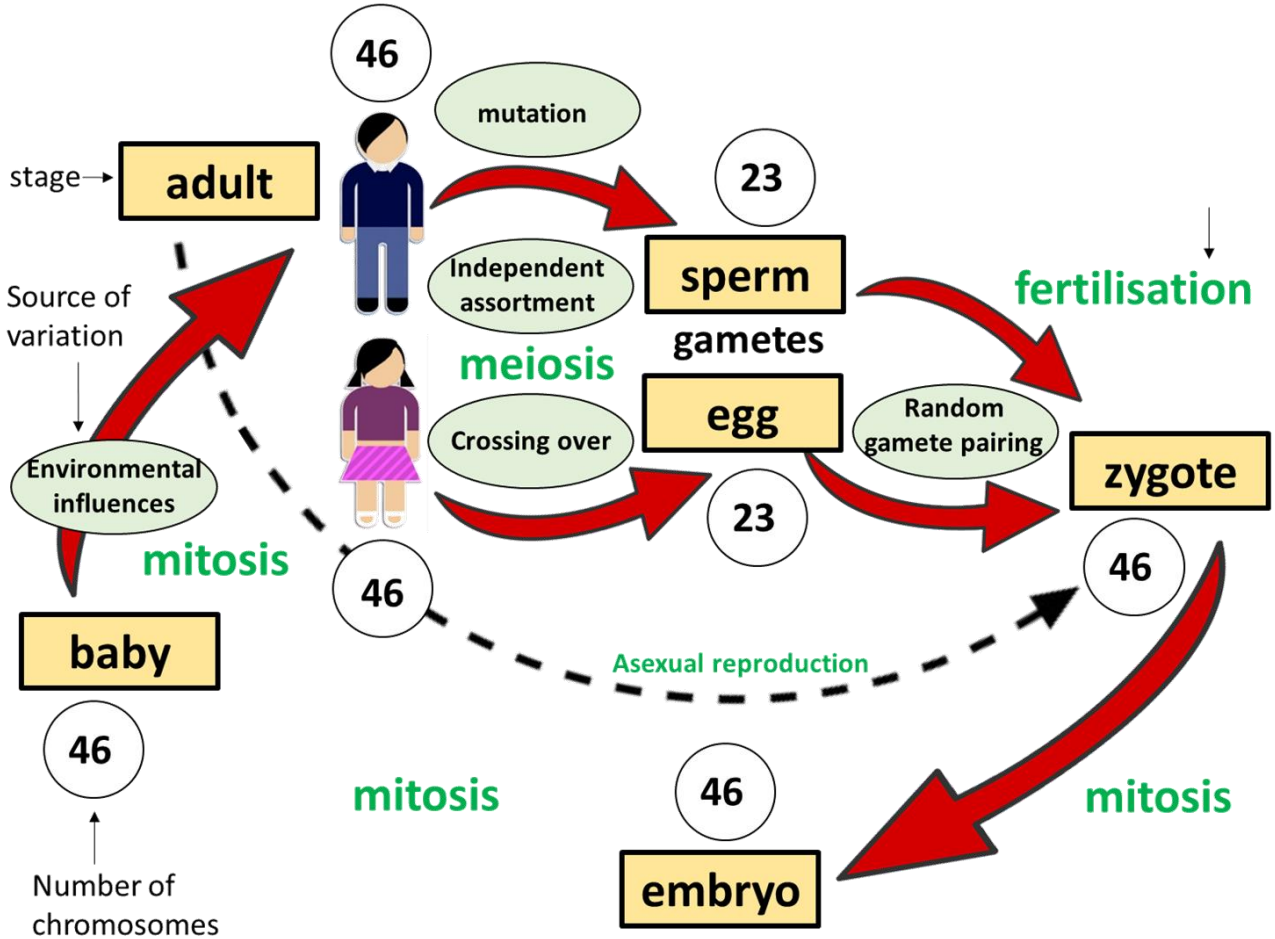
Answer 2c: The **egg and the sperm both have the same number of chromosomes (23)**. This is so that when fertilisation occurs, the chromosomes can exist as pairs. Chromosomes need to be in pairs so that they can separate in meiosis. The **zygote and the adult cells are both the same (46)** , because every cell in the body needs an identical and full copy of all the genetic information. The number of chromosomes in the gametes is half the number in the body cells, so that when fertilisation occurs, the chromosome number returns to its full number.

NCEA 2015 Sexual reproduction - disease in plants (PART ONE)

Merit Question

Question 3b (i) : The plants were grown from seeds. Seeds are the result of sexual reproduction.
(i) Name one process that occurs during sexual reproduction, and explain how it results in variation.

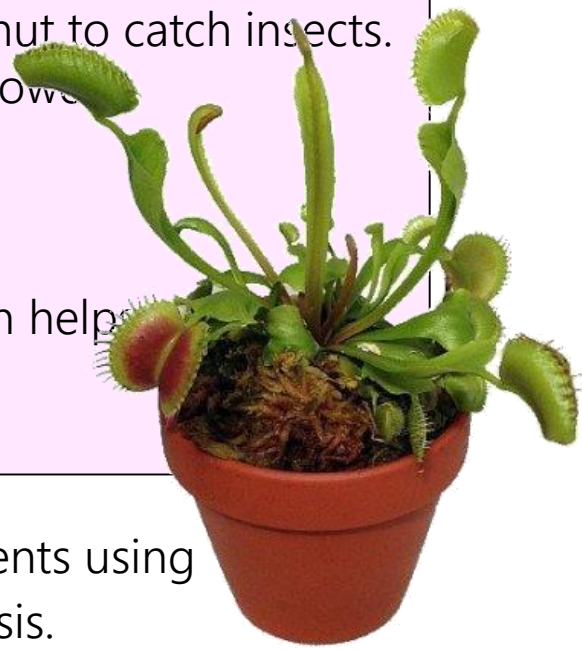
Answer 3a:
Sexual reproduction has the following processes that all contribute to variation in the offspring: meiosis / mutations / fertilisation / crossing over / independent assortment/ segregation



NCEA 2016 Sexual reproduction – venus fly traps

Excellence Question

Question 2c: Venus flytraps (*Dionaea muscipula*) are plants that live in poor quality soils. They have specially adapted leaves that snap shut to catch insects. The plants reproduce sexually, involving the production of flow
(a) Discuss the advantages of sexual reproduction.
In your answer you should:
• define sexual reproduction
• explain how ONE important process in sexual reproduction help
produce variation in offspring
• plant population over generations.



Sexual reproduction involves combining DNA from two parents using gametes. These gametes (sex cells) are formed during meiosis.

Gametes have only one set of chromosomes, and so these can be combined with another parent to make a unique individual. This increases variation [OR crossing over OR independent assortment OR meiosis OR fertilisation].

Variation means that some plants will be better suited to conditions, and so will survive better. For example, they might produce deeper roots (or more traps, or more effective traps, etc.). These better adapted plants will produce more offspring, and so over time the **population** can adapt. If all Venus flytraps were the same, they may all die from the same disease or the same set of unfavourable environmental conditions.

Excellence Question (with b)

NCEA 2017 Sexual reproduction variation – Bananas

Question 3a: Wild bananas have large seeds, and reproduce sexually. Farmed bananas are produced asexually, from suckers called "banana pups".
(a) How does the production of **gametes** result in variation for the wild banana plants?

http://www.nzqa.govt.nz

A **gamete** is a sex cell with one set of chromosomes (instead of the normal 2). **Variation** is the differences within a species. Sexual reproduction involves combining gametes from 2 parents to create a new individual. Each parent contributes a single copy of each chromosome to a gamete. Therefore, when these are combined (forming the zygote), the offspring has the combined information from 2 individuals. As the chromosomes are shuffled randomly during meiosis every gamete is different, and so each individual (even from the same 2 parents) is a unique combination of its parent's alleles.
In this way, meiosis increases variation, for example, some bananas might have more or fewer seeds, or bigger fruit, or
grow taller.

https://commons.wikimedia.org/w/index.php?curid=1867879 (cc)

Wild bananas, showing seeds.

A "banana pup" growing.

NCEA 2018 Sexual reproduction variation - Ryegrass

Excellence Question

http://www.nzqa.govt.nz

Question 2b: Explain how sexual reproduction increases variation in the Italian ryegrass population. Your answer should include **gamete formation** and **fertilisation**.

Sexual reproduction is producing offspring by combining **DNA** from two parents using **gametes**. These gametes (sex cells) are formed during **meiosis**.
Parents have two sets of chromosomes in each cell. The gametes produced in sexual reproduction have only one set of chromosomes, and so these can be combined with another parent to make a unique individual. This is called **fertilisation**.
When these gametes are formed, one of each chromosome pair is passed on. These chromosomes are **randomly assorted**, meaning there are many different gametes that one plant can produce.

NCEA 2019 Sexual reproduction variation – Kauri Dieback

Excellence Question

Question 3a: The kauri dieback disease damages the tissues that carry nutrients within the kauri tree. This means some trees survive and others starve to death.
(a) Describe genetic variation in kauri trees.

http://www.nzqa.govt.nz

https://www.rnz.co.nz/national/programmes/insight/audio/2018623809/insight-kauri-dieback-can-these-noble-trees-be-protected

Defines genetic variation differences in DNA / genes / alleles / physical appearance of kauri trees.

NCEA 2019 Sexual reproduction variation – Kauri Dieback

Excellence Question

Question 3b: Explain how the sexual reproduction of kauri trees causes genetic variation AND how this could lead to increased survival of the species when faced with kauri dieback disease.
In your answer you should consider:
- the processes of gamete formation (meiosis) and fertilisation
- how sexual reproduction leads to variation in the population
- the link between genetic variation and the survival of kauri trees as a species.

http://www.nzqa.govt.nz

Gamete formation by meiosis: Random assortment/segregation / crossing of chromosomes over in meiosis
Description of meiosis: produces gametes / sex cells that have half the normal number of chromosomes as body cells.
Process of fertilisation: Random male and female gametes join, each with unique DNA producing a genetically unique zygote / offspring.
Role of sexual reproduction: produce new combinations of alleles and thus genetic variation between individuals.
Explanation: The advantage of genetic variation to a species is that it may enable some individuals to survive kauri dieback to reproduce, passing on favourable alleles / genes to the next generation. Over many generations this genetic advantage / genes / alleles will rise in the population, allowing survival of the kauri species.

Organisms vary and that some variations give advantages over others in a given environment

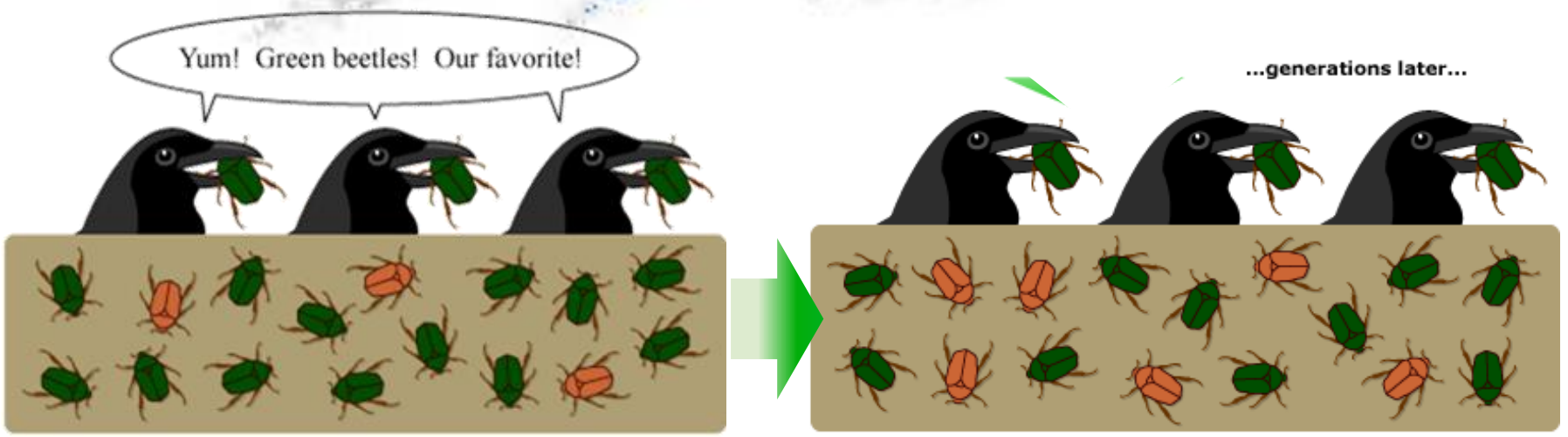
Adaptations of a New Zealand kakapo include mossy green colouring for camouflage, and a stout ridged bill to cut through tough plant material

https://www.tumblr.com/search/strigops%20kakapo

Individuals of a species occupy a **niche** and they have **adaptations** to survive in their habitats. The adaptations may help them to best obtain food, seek mates, raise offspring, find shelter or escape predators.

Adaptations are physical characteristics (phenotypes) 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.

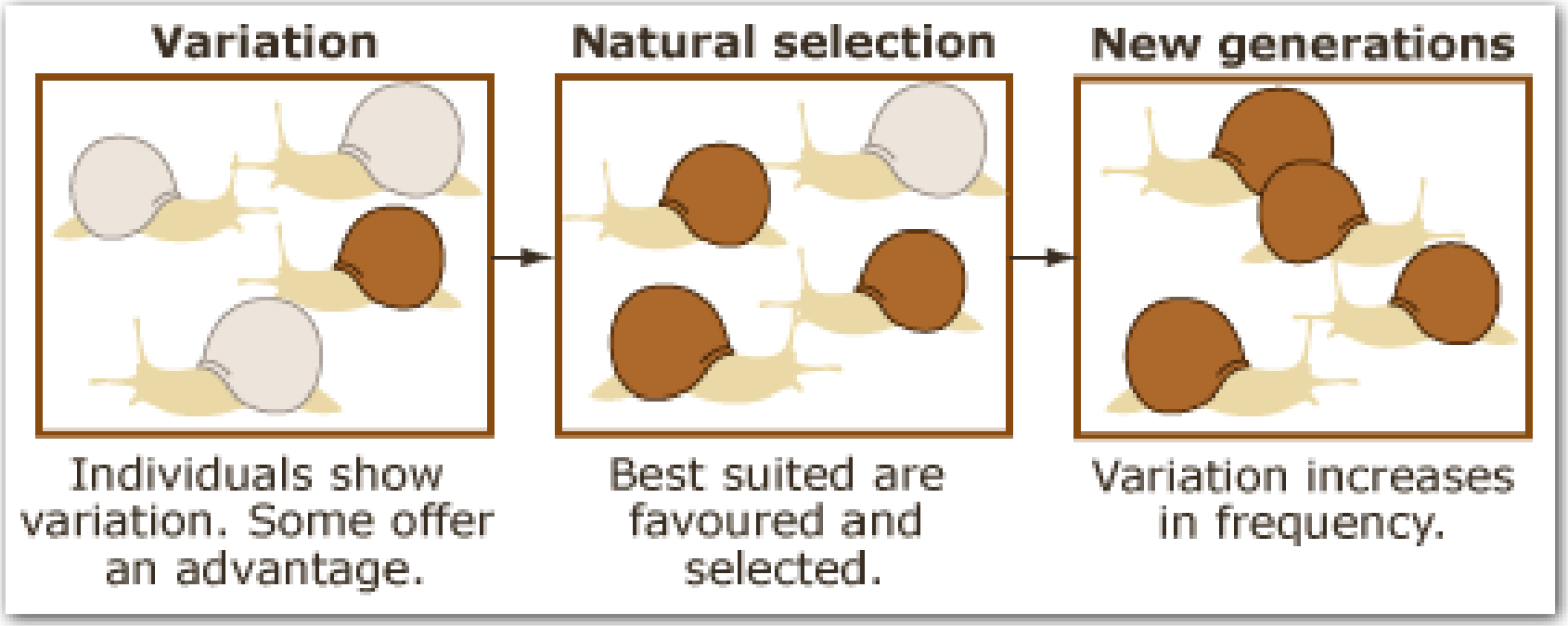
Variations caused by genes can be passed on to offspring and that genes conferring advantageous adaptations are more likely to be passed on than others



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 (genotype) will be born.

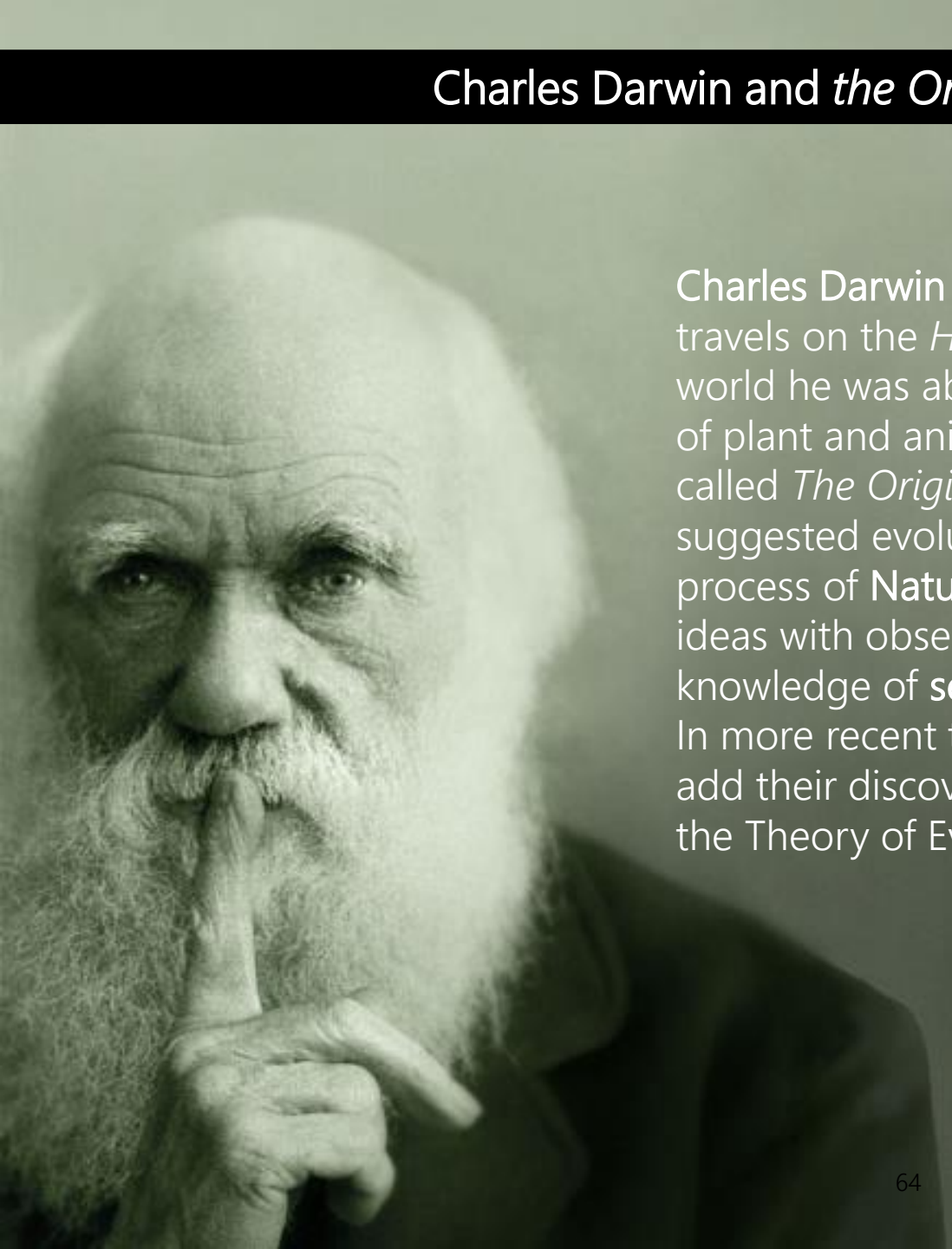
Natural Selection

Natural selection occurs when environmental factors may favour certain variations of physical characteristics (phenotypes) and selects for or against it, and its underlying genes (genotypes).



https://danielnevolution.weebly.com/natural-selection.html

Charles Darwin and *the Origin of Species*



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**.

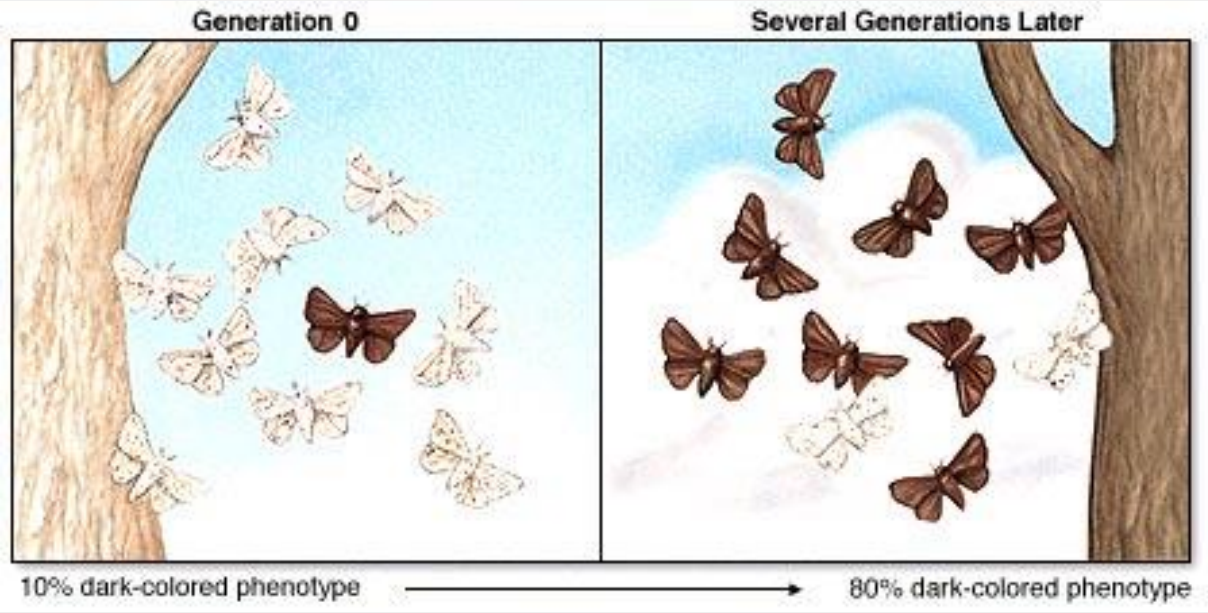
In more recent times Scientists have been able to add their discoveries of **Genetics** to further support the Theory of Evolution.

Background Knowledge

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.



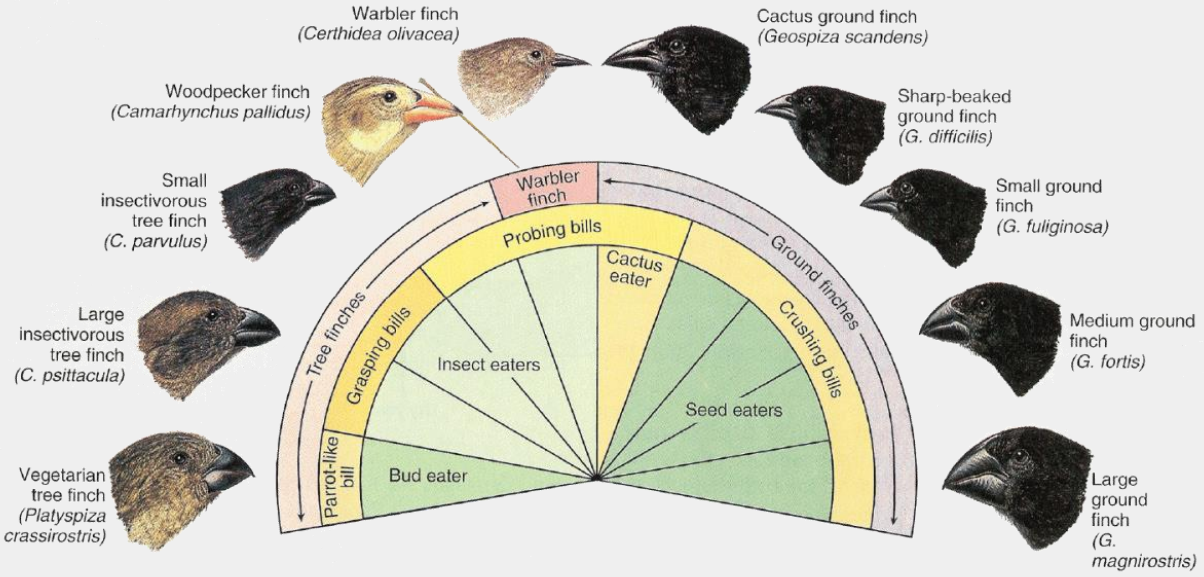
Background Knowledge

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

GZ Science Resources

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.

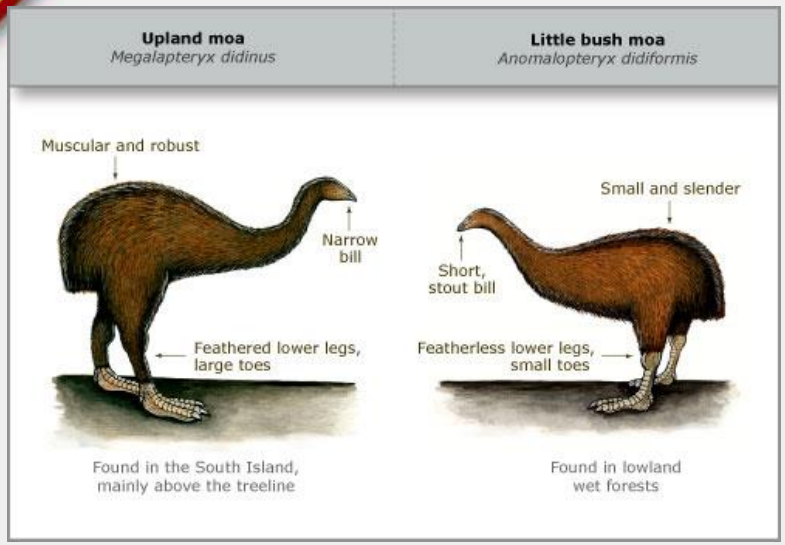
The evolution of the Galapagos finches from an ancestral finch



Background Knowledge

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

GZ Science Resources



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.

Background Knowledge

Evidence for Evolution

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.

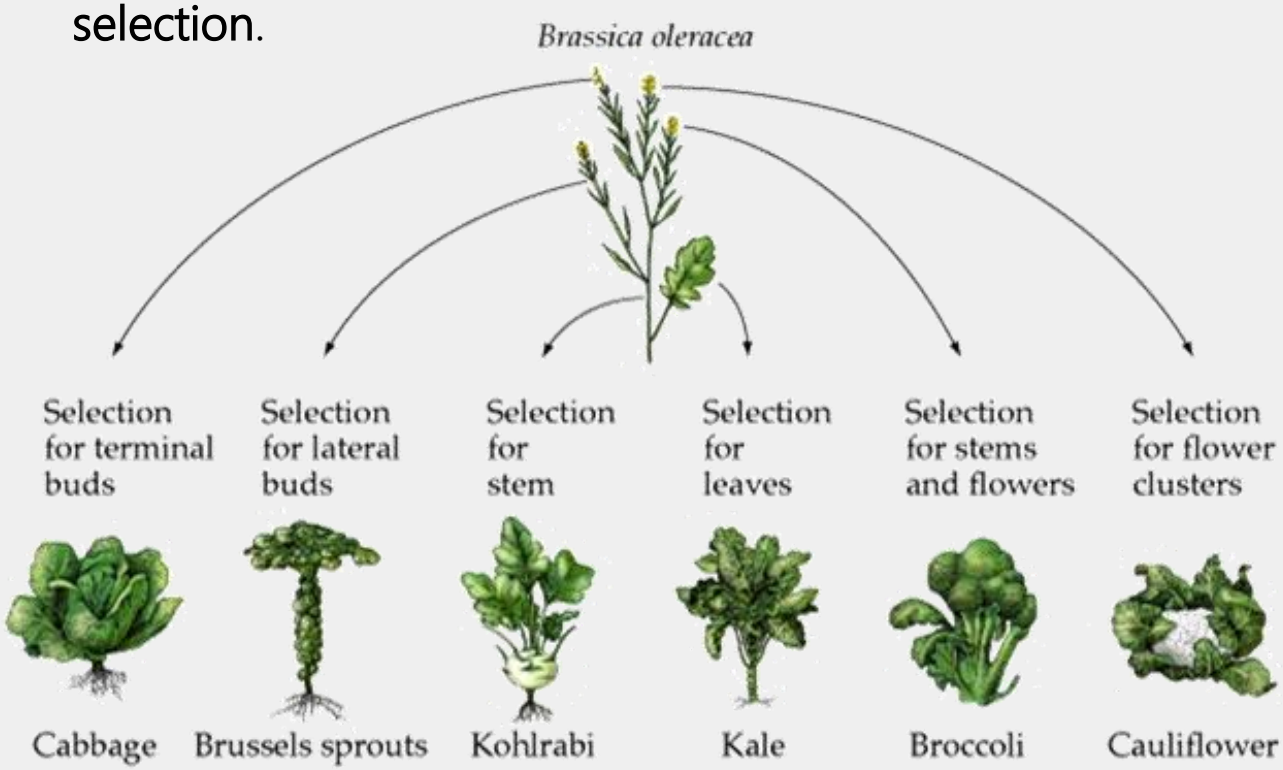
Biogeography or how species are distributed around the world gives us evidence to the relationships between species.

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

Background Knowledge

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**.



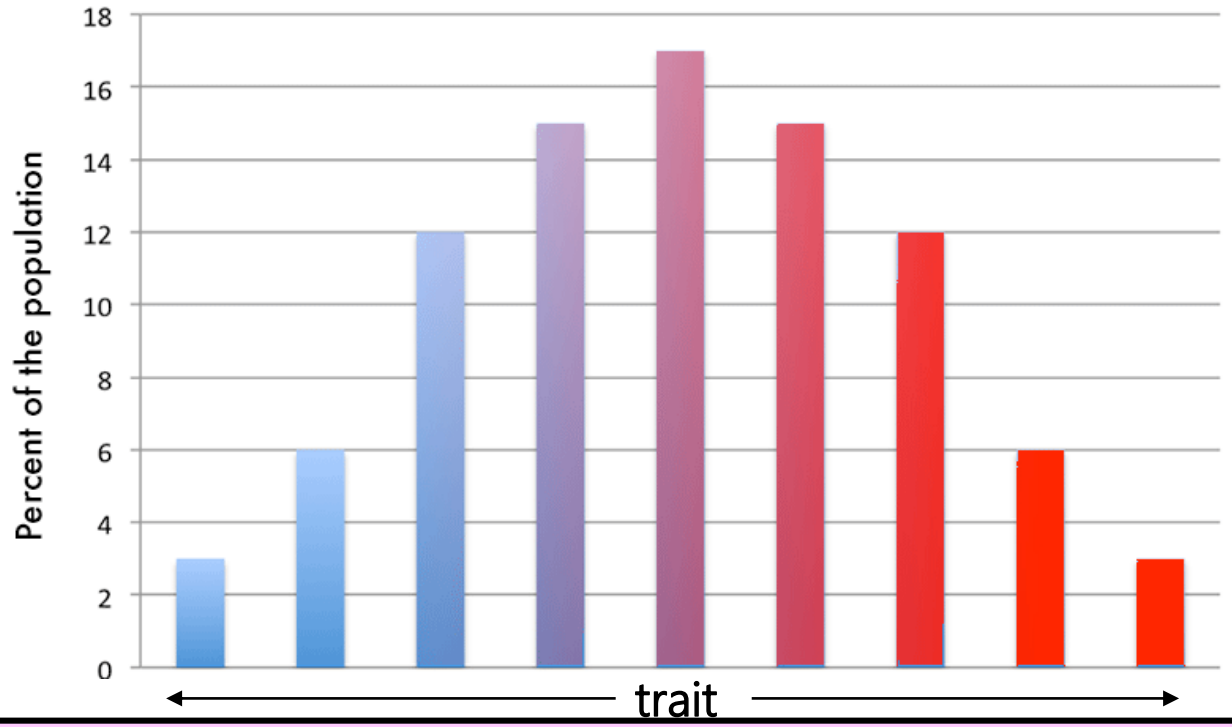
Why is variation so important for a species survival?

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.

Why is variation so important for a species survival?

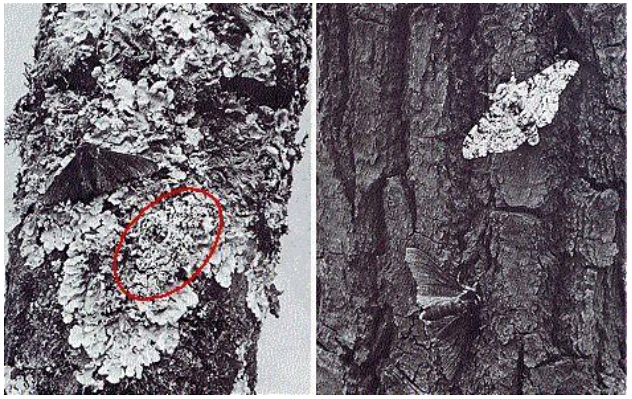


During a "typical" season in any environment, an average phenotype for any particular trait is most likely to be best adapted to the environment and therefore the organism having it will have the best chance for survival. Those "average" phenotypes are likely to make up the largest percent of the population.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

- define phenotype
- explain how colour helps individual moths to survive
- explain why the environmental change to darker trees, affects the ratio of the phenotypes in the moth population over time.



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.

Sexual Reproduction – NCEA case study

Q: Explain how sexual reproduction causes genetic variation AND how this leads to increased survival of the species.

In your answer you should consider:

- the processes of gamete formation (meiosis) and fertilisation
- how sexual reproduction leads to variation in the population
- the link between genetic variation and survival of a species.

Meiosis produces gametes which have half the normal number of chromosomes as body cells. In **fertilisation random male and female gametes join** and produce a unique zygote. The role of sexual reproduction is creating variation in offspring by the **independent assortment of chromosomes** and **crossing over in meiosis** and **random fertilisation** of the gametes.

Genetic variation refers to a variety of **different genotypes for a particular trait** within a population. The advantage of variation to a species is that it may enable some individuals to survive if some threatening event or sudden change in the environment occurs, eg disease or drought, as they will reproduce and pass on favourable phenotypes to strengthen the species.

NCEA 2013 Survival in Changing environment

Tasmanian Devil case study

Excellence Question

Tasmanian Devils are a species of meat-eating marsupial mammal native to Australia.They are the size of a small dog, and the males especially, are very aggressive towards each other most of the time. Aggression is a behavioural phenotype that is controlled by genes.

Tasmanian Devils aggression helps males fight off competitors from breeding females therefore ensuring their genes get passed to the next generation. Aggressive behaviour also ensures survival of an individual when born. A female Tasmanian Devil gives birth to 20-30 small young but only has 4 milk teats in her pouch.

However, aggression costs the animal energy and risk of injury so it can also reduce the survival rate of an individual if the behaviour becomes excessive.

Variation of the aggressive behaviour trait in the population of Tasmanian Devils helps the species survive.

The more aggressive Tasmanian Devils survive when there is a lack of mates or food for the females to produce milk. The more peaceful Tasmanian Devils survive when there is plenty of food and mates and they suffer less injuries, while conserving energy.

NCEA case study

NCEA 2013 Survival in Changing environment – Tasmanian Devil

Excellence Question

Question 4b: Explain how the survival of certain individuals in the wild within the Tasmanian devil population can change the ratio of aggressive to less aggressive types of Tasmanian devil within the species over time AND relate this to the species avoiding extinction.

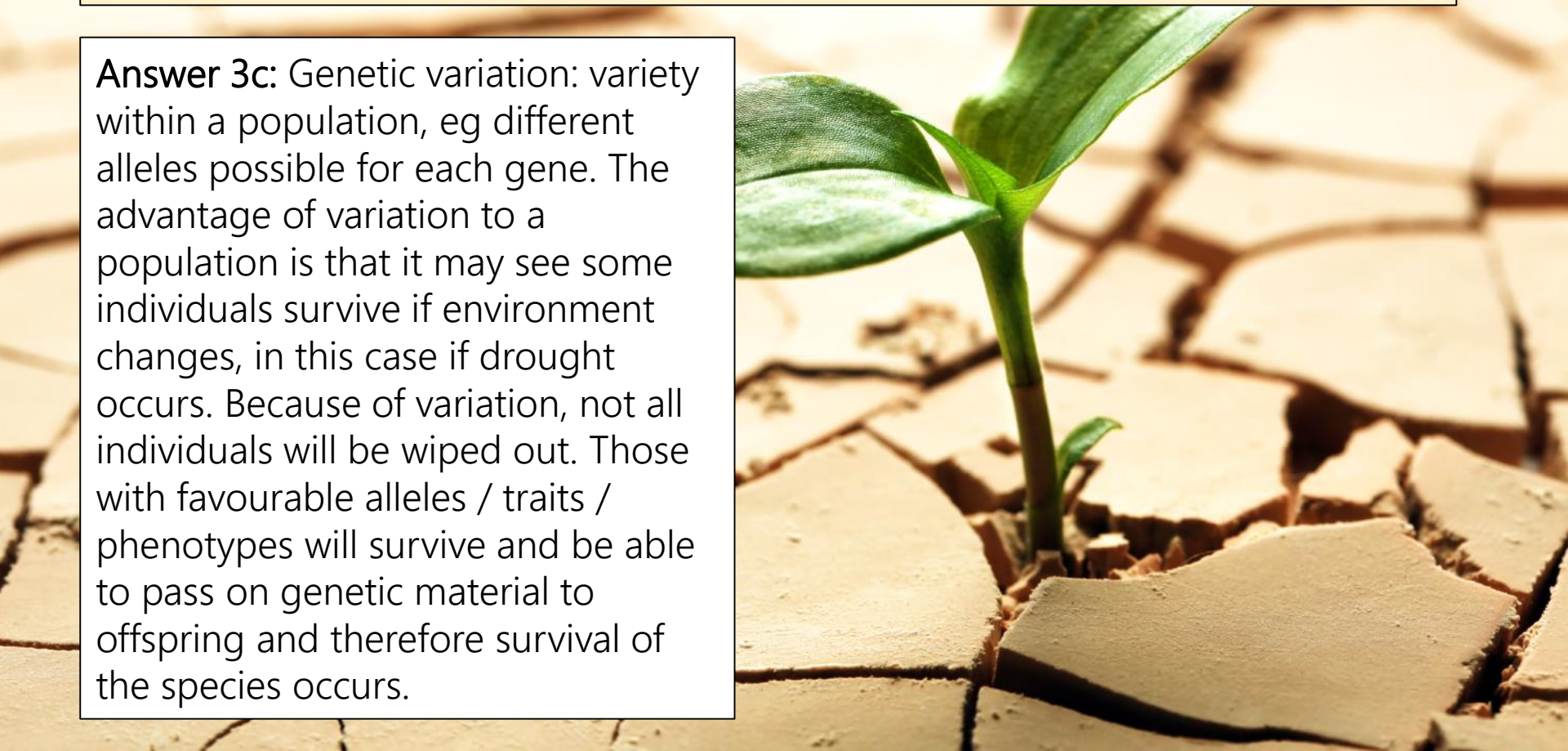
Answer 4b: The aggressive devils have decreased life expectancy due to increased disease and injury, therefore have fewer breeding cycles and consequently have fewer offspring during their shortened life.
The unaffected devils have a normal life expectancy and therefore more breeding cycles, resulting in more offspring during the lifetime of the individual.
The less aggressive trait has a greater chance of increasing in the population as there will be more of them to reproduce.

NCEA 2013 Survival in Changing environment – Drought

Excellence Question

Question 3c: Discuss why variation caused by sexual reproduction in a population of plants or animals is an **advantage** in a changing environment, such as a period of drought (a period of time of very dry weather, when there is no or very little rain).
Support your answers with examples.

Answer 3c: Genetic variation: variety within a population, eg different alleles possible for each gene. The advantage of variation to a population is that it may see some individuals survive if environment changes, in this case if drought occurs. Because of variation, not all individuals will be wiped out. Those with favourable alleles / traits / phenotypes will survive and be able to pass on genetic material to offspring and therefore survival of the species occurs.



NCEA 2014 Survival in Changing environment - disease in plants

Excellence Question

Question 1c (ii) : The pictures below show two plants of the **same** species. Discuss how BOTH inheritable and non-inheritable factors can result in the variation of these plants, AND explain the importance of this variation within a large population of the plants growing in a changing environment.

Answer 1c(ii): The phenotype is the physical characteristic of the plant. Variation that is inheritable is due to **differences in the alleles** (or genetic material). This comes from meiosis, eg independent assortment / gametes with ½ chromosomes so mix of 2 parents. Non inheritable variation is due to **environmental factors**. In plants this could be plenty of water or sunlight, enabling the plant to grow taller, or a lack of water limiting the plant's growth. It is the combination of both the inheritable and non-inheritable factors that determines the phenotype. For example a plant might have two alleles coding for a tall plant, but if there is a lack of water the plant will not grow to its genetic potential. Variation is important because if **environmental conditions change**, some plants may not be suited to the new conditions and may not survive, but other plants, which are different, may be suited to the new conditions and can survive.

Discussion of inheritable **and** non-inheritable/ environmental factors (with examples) resulting in variation of phenotypes / characteristics.

NCEA 2015 Survival in Changing environment

Excellence Question

Question 3b (ii) : Discuss the advantages of sexual reproduction for a species when the environment changes.
In your answer you should:
- give examples of a changing environment
- explain the impact of changing environments on a population
- consider the importance of variation in a population in a changing environment.

Answer 3b (ii) : Sexual reproduction results in variation, which is important in a changing environment. As the environment changes some individuals may not survive. If there is variation in their alleles / DNA / genes, some individuals may have phenotypes that are more suited to the environment; therefore they will be more likely to survive. The individuals that survive when they reproduce will pass these alleles / DNA / genes to the next generation, helping to ensure the survival of the species.

Excellence Question (with a)

NCEA 2017 Survival in a changing environment – Bananas

Question 3b: Suggest a possible problem that may arise with farmed bananas (produced from suckers), and explain why this problem would not occur in wild bananas (produced sexually)?

http://www.nzqa.govt.nz

https://www.livescience.com/45005-banana-nutrition-facts.html

Farmed bananas are produced asexually – there are no gametes and so they are not varied. That means one disease could potentially harm them all. The world supply of farmed bananas is susceptible to disruption by disease like this.

Whereas due to variation (from meiosis), the wild bananas may have individuals that are resistant to the disease and pass this on to their offspring. In this way, the wild banana population can become immune / adapt to conditions. **Wild bananas** are produced through **sexual reproduction**. The offspring show variation from each other and their parents. Genetic variation is variety within a population, e.g. different alleles possible for each gene. The advantage of variation to a population is that it may see some individuals survive if environment changes, in this case if drought occurs. Because of variation, not all individuals will be wiped out. Those with favourable alleles / traits / phenotypes will survive and be able to pass on genetic material to offspring and therefore survival of the species occurs.

NCEA 2018 Survival in a changing environment - Ryegrass

Excellence Question

http://www.nzqa.govt.nz

Question 2a: Herbicides are chemicals that are used to kill weeds. Over many years, Italian ryegrass (a common weed) has developed a resistance to some herbicides (it is no longer killed by them). (a) Explain how **variation** in the Italian ryegrass **population** can help the population develop herbicide resistance.

Variation is differences within a species, such as some Italian ryegrass plants being more resistant to herbicides than others. Those that are better suited to the conditions, in this case herbicide resistant, will survive better. These better suited plants are more likely to produce more offspring, and pass on their successful alleles / DNA / genes. The next generation will therefore be better suited than the previous generation. Over time, the population of Italian ryegrass will contain more plants that are herbicide resistant.

This will lead to an increase in number of plants able to resist herbicides and an increase in plant numbers. If all Italian ryegrass plants were the same, they would all die from the herbicide.

http://agfaxweedsolutions.com/2017/02/03/mississippi-corn-control-italian-ryegrass-planting/