Biology Paper 2 – Unit 6 Inheritance, variation and evolution

Reproduction

- Sexual and asexual reproduction
- Meiosis
- Advantages and disadvantages of sexual and asexual reproduction (biology)
- DNA and the genome
- DNA structure (biology)
- Genetic inheritance
- Inherited disorders
- Sex determination

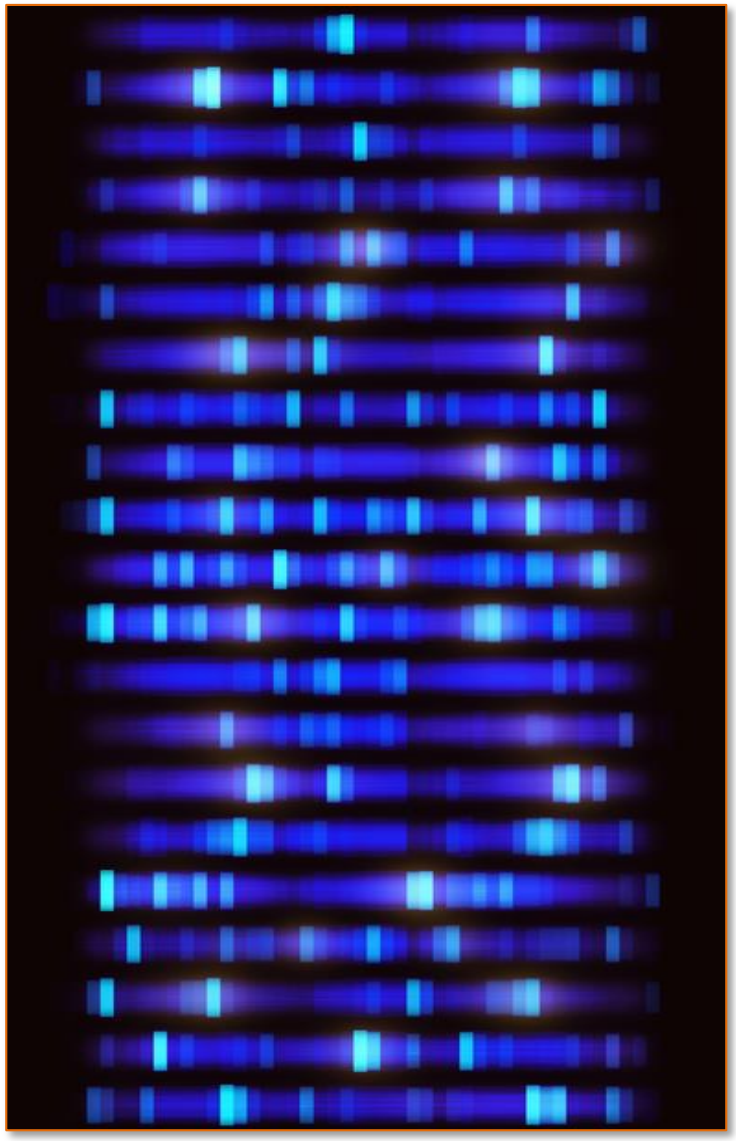
Variation and evolution

- Variation
- Evolution
- Selective breeding
- Genetic engineering
- Cloning (biology)

Development of understanding of genetics and evolution

- Theory of evolution (biology)
- Speciation (biology)
- Understanding of genetics (biology)
- Evidence for evolution
- Fossils and extinction
- Resistant bacteria

Classification of living organisms



LearnIT!

KnowIT!

Inheritance

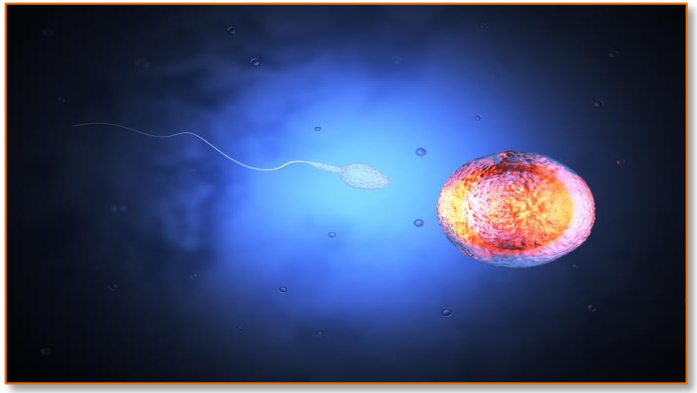
Part 1

- Reproduction
- Meiosis
- Advantages of sexual and asexual reproduction (biology)
- DNA and the genome
- DNA structure (biology)

Inheritance part 1 – Reproduction

Sexual reproduction involves the joining of **male** and **female** gametes.
A **gamete** is the scientific term for a sex cell.
In animals, the gametes are the **sperm** and the **egg** cells.
In flowering plants, the gametes are the **pollen** and the **egg** cells.

In sexual reproduction, **mixing** of **genetic information** occurs which leads to **variety** in the offspring.
Every new **offspring** formed is **unique**.
The gametes are produced by **meiosis**.



Asexual reproduction involves only **one parent**. There is **no fusion** of gametes. **No mixing** of genetic information occurs. **All** offspring are genetically **identical** (called **clones**). Only **mitosis** is involved.

Inheritance part 1 – Meiosis

Meiosis leads to **non identical** cells being formed.
Mitosis leads to **identical** cells (clones) being formed.

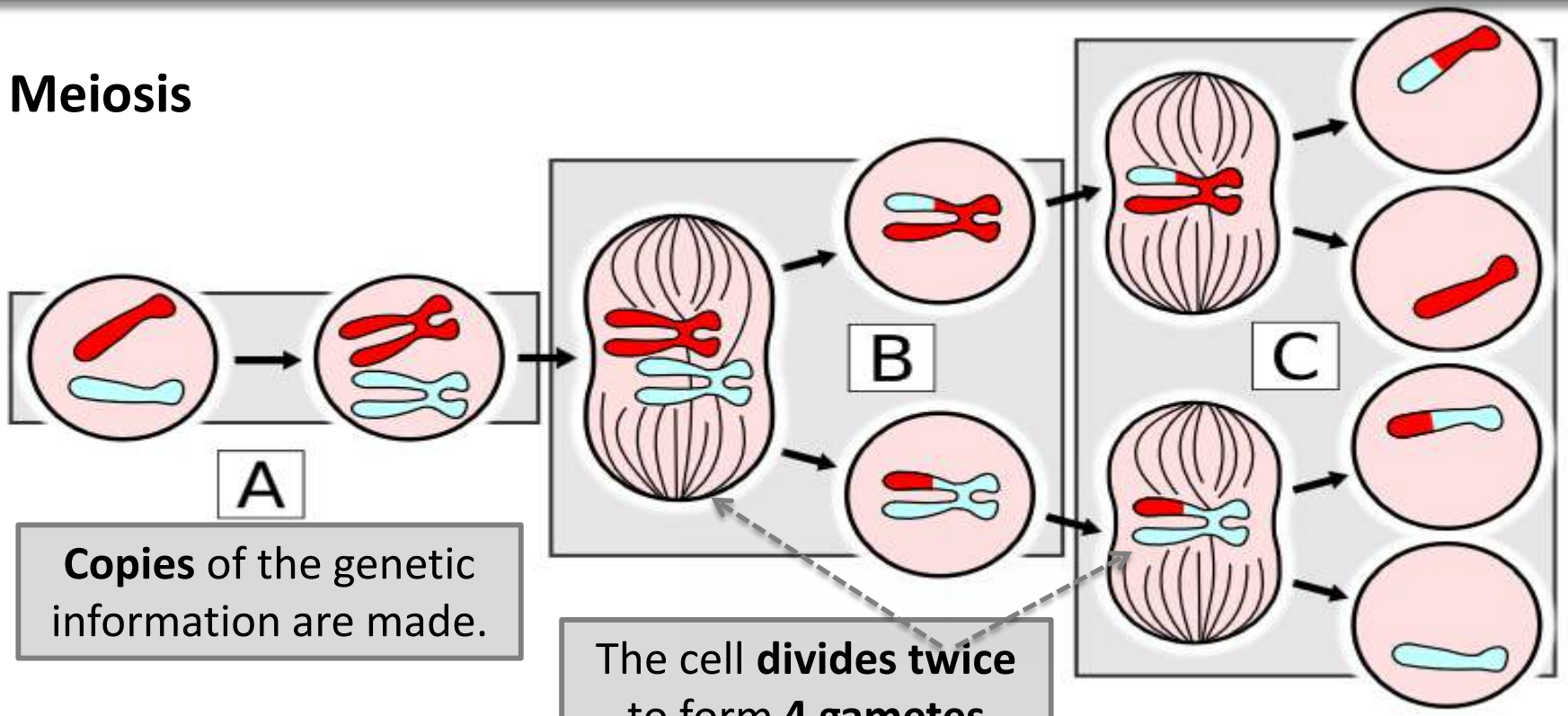
Cells in the **reproductive organs** divide by **meiosis** to form **gametes**. In animals, the reproductive organs are the **ovaries** and **testes**.

Meiosis is sometimes called **reduction division** because it **halves the number of chromosomes** in the gametes. When male and female gametes fuse during **fertilisation,** the number of chromosomes are restored.

This brother and sister have the same parents, but they look different. They show **variation** because of meiosis.

This is the process a cell goes through to produce gametes:

Meiosis



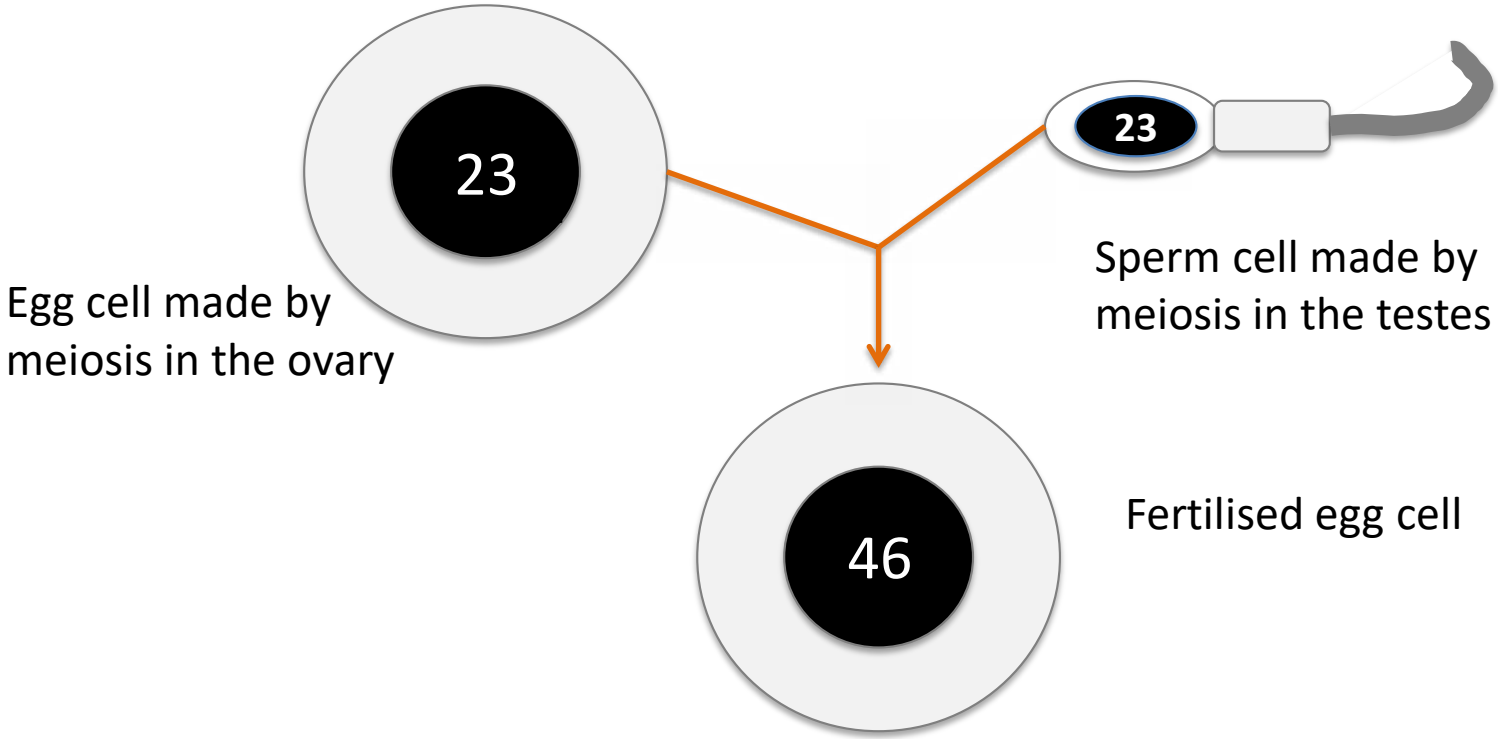
Copies of the genetic information are made.

The cell **divides twice** to form **4 gametes** each with a **single set** of **chromosomes**. This is **half** the number of the **original** cell.

All **4 gametes** are **genetically different** from each other and to the parent.

Inheritance part 1 –Meiosis

A cell in the testes has **46** chromosomes. When this cell undergoes meiosis it produces 4 gametes each with **23** chromosomes. The same process occurs in the ovary to produce egg cells.
The male and female gametes join at **fertilisation** to restore the normal number of chromosomes.
The fertilised egg cell now contains **46** chromosomes.

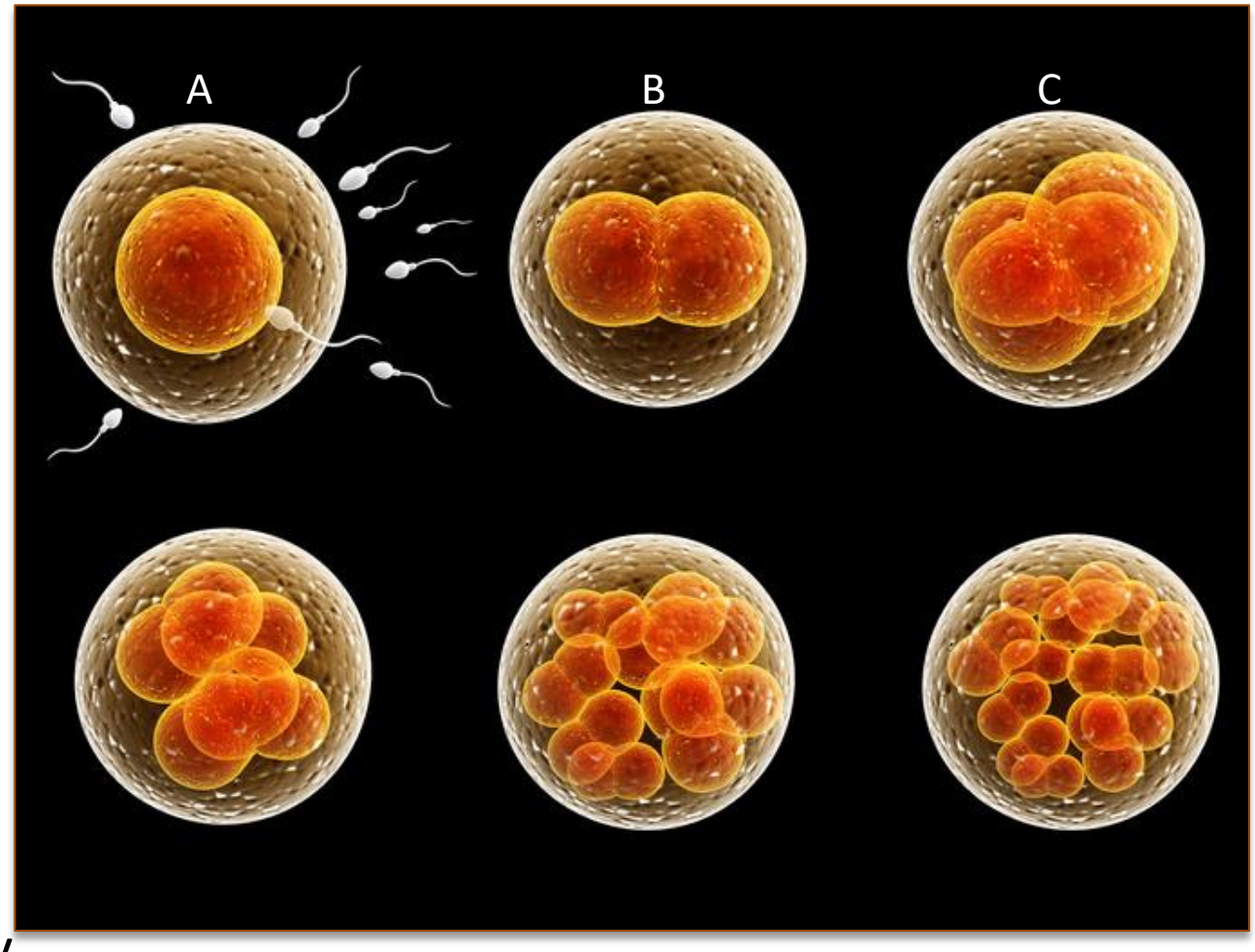


Inheritance part 1 – Meiosis

A Fertilisation occurs. The genetic material from the sperm and egg combine to form a **unique** cell.

B The fertilised cell divides by **mitosis** to form **2 identical cells.**

C Both cells divide by mitosis to form 4 identical cells.



Mitosis continues and a ball of identical cells is formed. This is now called an embryo. Cells now begin to differentiate into different types of cell.

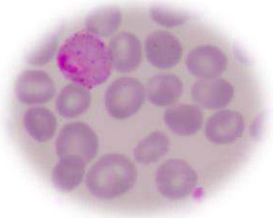
Inheritance part 1 – Advantages of sexual and asexual reproduction (biology only)

There are **advantages** to both **sexual** and **asexual** reproduction.

Advantages of sexual reproduction	Advantages of asexual reproduction
Variation occurs in the offspring.	Only one parent is required so it is a **more efficient** use of time and energy as **do not** need to find a **mate.**
If the environment changes, variation will give a **survival advantage by natural selection**. There is a better chance of at least some organisms surviving.	**Many identical offspring** can be produced if conditions are favourable.
Natural selection can be **manipulated** and sped up by **humans**, by **selective breeding** to increase food production.	Occurs **faster** than sexual reproduction.

Inheritance part 1 – advantages of sexual and asexual reproduction (biology only)

There are advantages to sexual and asexual reproduction, so some organisms **reproduce using both methods** depending on the circumstances:

Malarial parasites		Reproduce **asexually** in the **human** host, but **sexually** inside a **mosquito**. Video
Fungi		Reproduce **asexually** by **spores**, and **sexually** to give **variation**.

When **daffodils** flower they produce **seeds**. This is **sexual** reproduction.

Daffodils also reproduce **asexually** by **bulb division**.

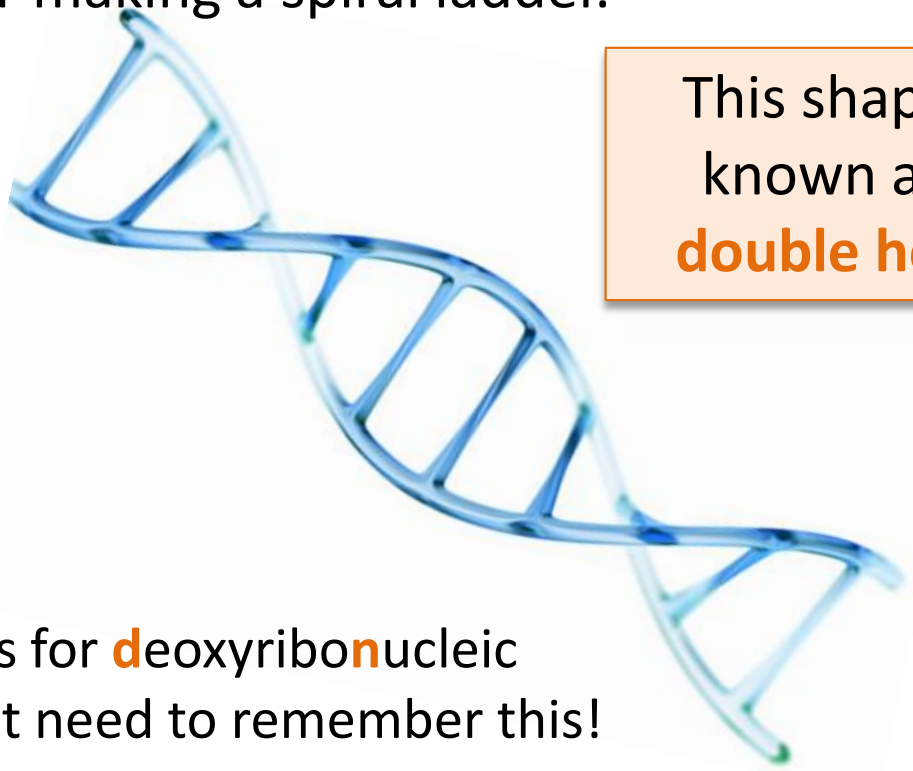
Strawberry plants produce **seeds sexually** and reproduce **asexually** using **runners**. A genetically identical plant forms at the end of the runner.

Inheritance part 1 – DNA and the Genome

The **genetic material** in the nucleus of most cells is made from a chemical called **DNA**.

DNA is a **polymer** made from two strands which twist around each other making a spiral ladder.

A **polymer** is a large molecule made from many **smaller** molecules called **monomers**.

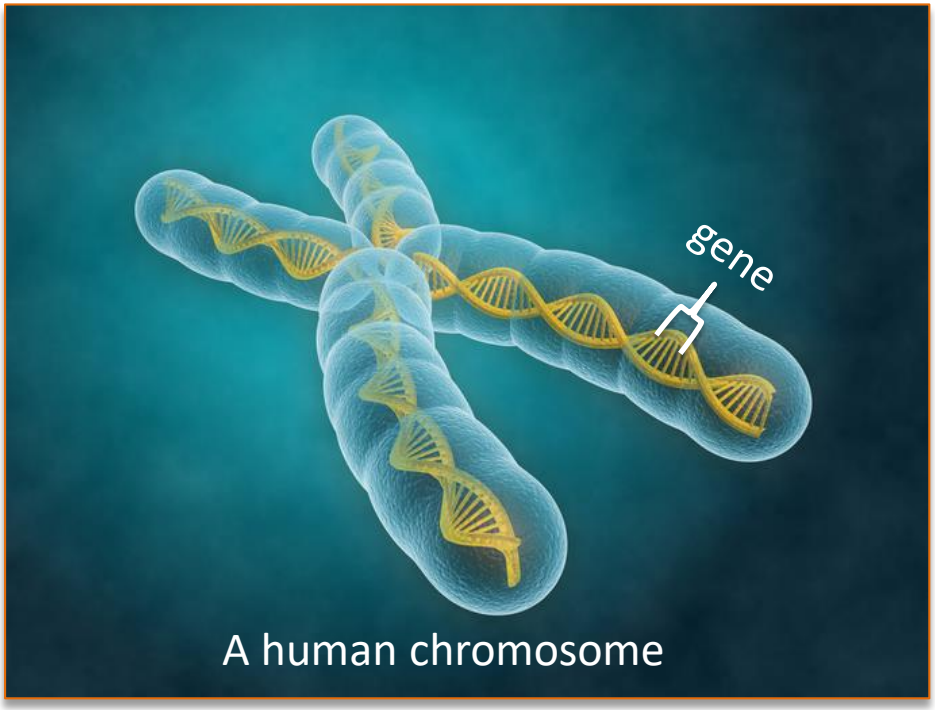


This shape is known as a **double helix**.

DNA stands for **d**eoxyribo**n**ucleic **a**cid. You don't need to remember this!

Inheritance part 1 – DNA and the genome

DNA is arranged in structures called **chromosomes** inside a cell's nucleus.



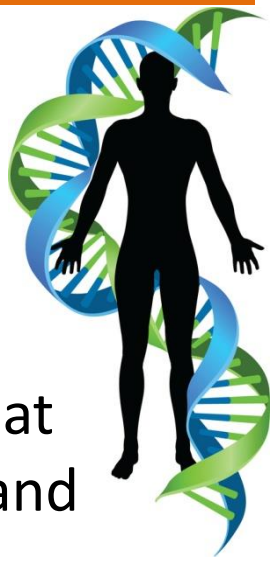
A human chromosome

A **gene** is a small section on a chromosome. Each gene **codes** for a particular sequence of **amino acids**, to make a specific **protein**.
A human has approximately 24 000 genes in total. Each single chromosome is made up of about 2000 genes.

In human body cells the **chromosomes** are normally found in **pairs**. Each cell has **23 pairs** of chromosomes.
The chromosome number varies from one organism to another.
A **horse** has **32 pairs** of chromosomes and a **housefly** has **12 pairs**.

Inheritance part 1 –DNA and the genome

The **genome** of an organism is defined as the **entire genetic material** of that organism.



The **Human Genome Project** (HGP) was an international scientific research project set up to **map all the genetic information** in a human being.

It began in 1990 and was completed in 2003. The whole **human genome has now been studied** and this will have great significance for **medicine** in the future. This work to understand the human genome is important for several reasons:

- ❑ To enable scientists to search for the **genes linked to different types of disease** to look for possible treatment or correction
- ❑ To enable doctors to better **understand and treat inherited disorders**
- ❑ To be able to trace historic **human migration patterns.** **video**

Inheritance part 1 – DNA structure (biology only)

DNA is made from repeating monomers called **nucleotides**. There are **4 different nucleotides**. The long strands of DNA consist of alternating sugar and phosphate sections.

Each nucleotide is made from three components:

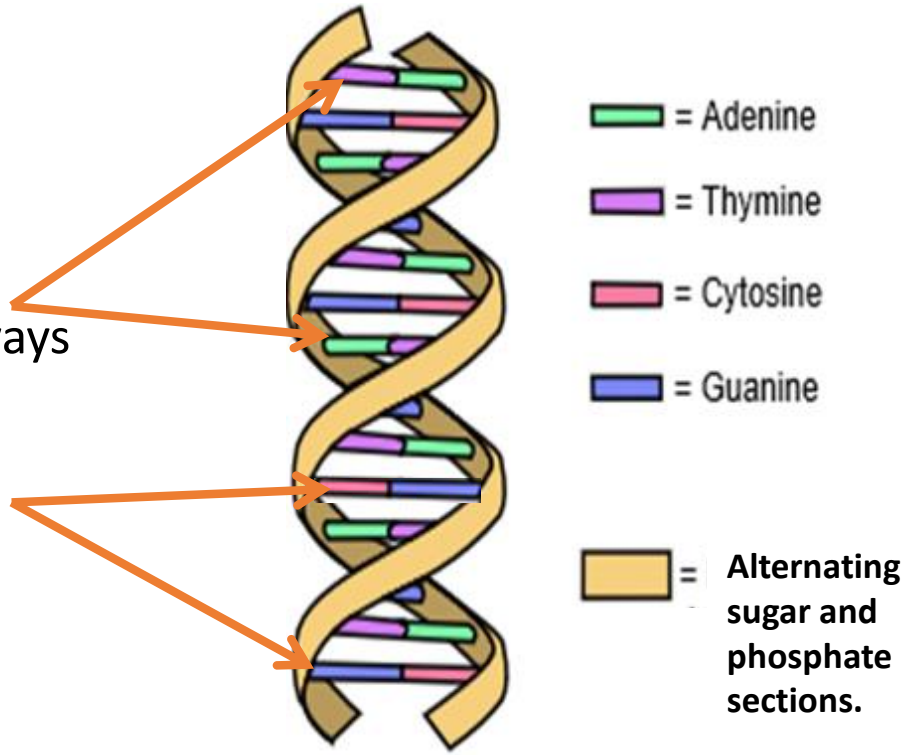
- **A phosphate group**
- **A simple pentose sugar (this means it contains 5 carbon atoms)**
- **A base**

There are **4 bases in DNA**.
Adenine (A), thymine (T)
guanine (G) and cytosine (C)

Notice in the diagram that **adenine** always pairs up with **thymine** or vice versa.

Cytosine always pairs up with **guanine** or vice versa.

This is called **complementary** pairing.



Inheritance part 1 – DNA structure (biology only)

Proteins have many different vital functions in our body.

- **Enzymes** – all made from protein.
- **Hormones** – all made from protein
- **Antibodies** – all made from protein
- **Structural** components such as muscle, hair and nail tissue.

Genes provide the **instructions** to make the **required protein** from **amino acids**.

It is estimated there are over 2 million proteins in a human body and all are made from combinations of just 20 different amino acids.

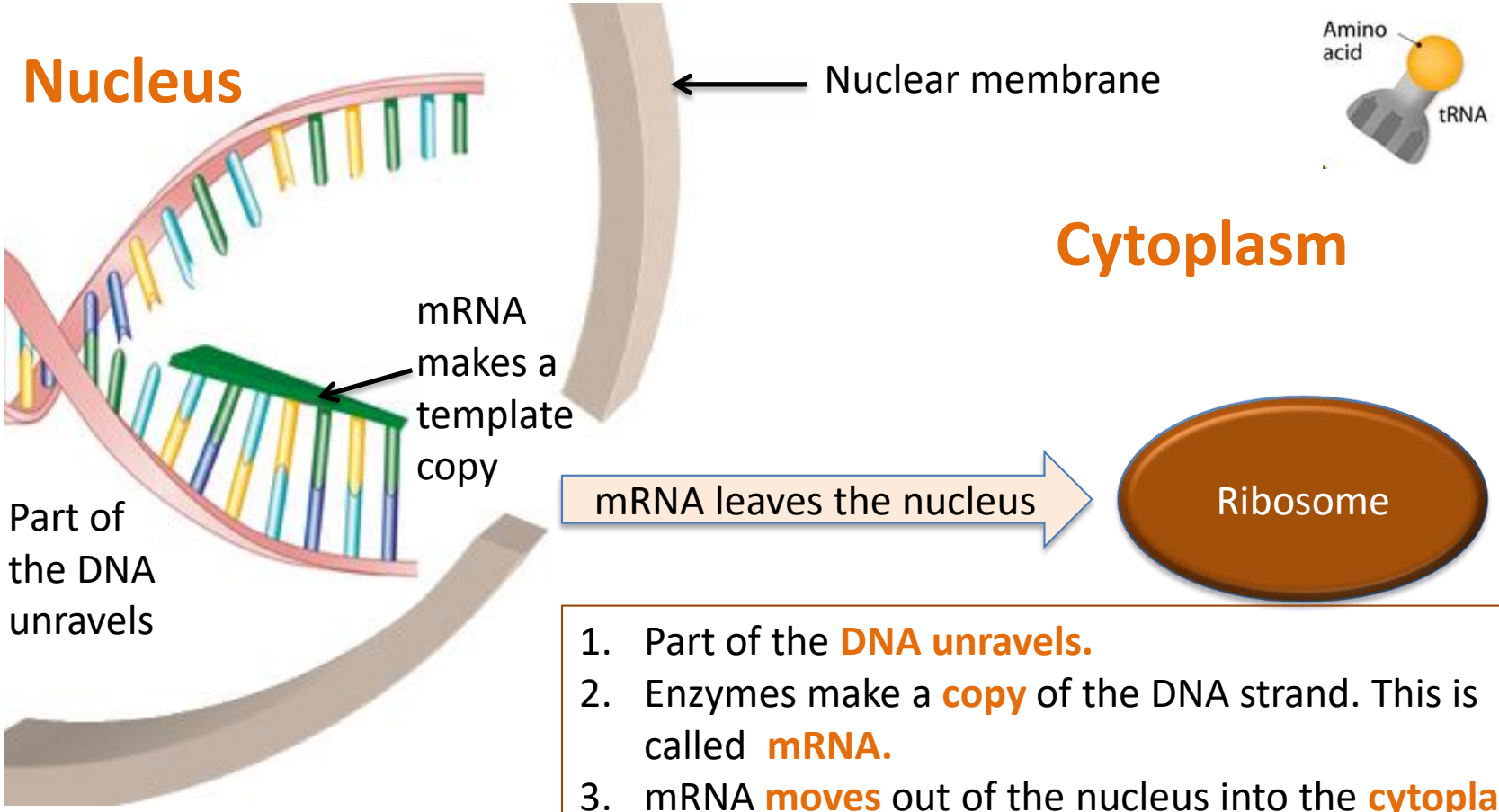
A sequence of **three bases** is the **code** for a particular **amino acid**.

The **order** of the **bases** controls the **order** in which **amino acids** are **assembled** to produce an individual protein.

Inheritance part 1 – DNA structure (biology HT only)

Making new proteins (Protein synthesis)

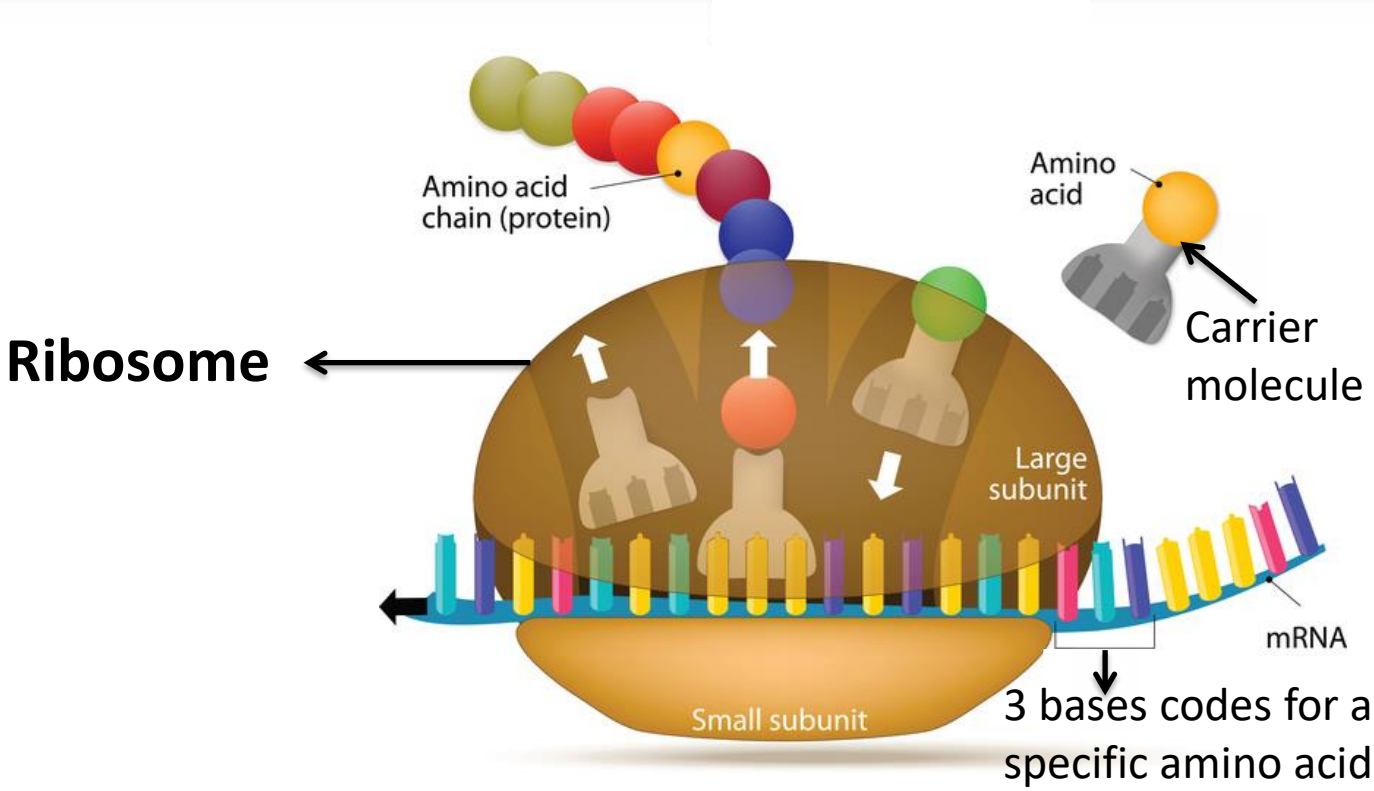
DNA is found in the **nucleus** of a cell, but **proteins** are **made** in the cytoplasm on **ribosomes**.

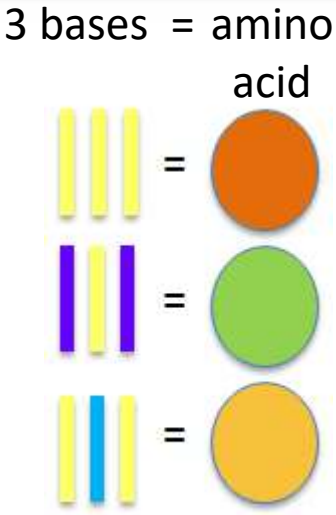


1. Part of the **DNA unravels.**
2. Enzymes make a **copy** of the DNA strand. This is called **mRNA.**
3. mRNA **moves** out of the nucleus into the **cytoplasm.**

Inheritance part 1 –DNA structure (biology HT only)

4. The mRNA travels to the **ribosome** in the cytoplasm.
5. Ribosomes **translate** each set of **3 bases** into **amino acids** according to the **mRNA template**.
6. Amino acids are found in the cytoplasm. The **correct amino acid** for each set of 3 bases is brought to the **ribosome** by a **carrier molecule**.
7. A **long chain** of amino acids form. Their **specific order** forms a **specific protein**.

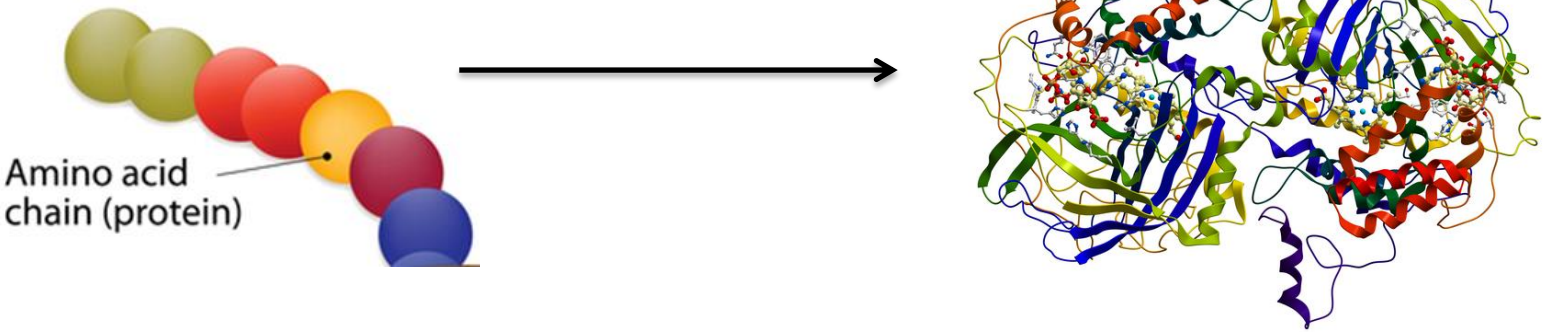




Inheritance part 1 – Reproduction (biology HT only)

When the **protein chain** is complete, it **folds up** to form a **unique** shape.
This unique **shape** allows the protein to carry out its **role effectively**.

This could be as an enzyme, hormone or structures in the body such as collagen.

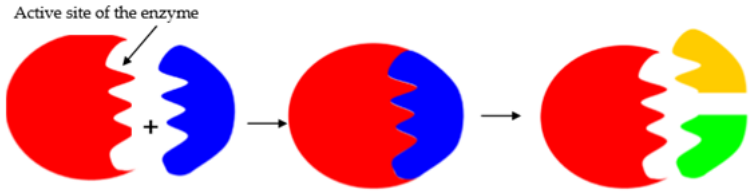


An enzyme

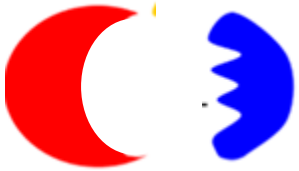
Inheritance part 1 – DNA structure (biology HT only)

Mutations occur continuously during cell division. **Most of the time** when a mutation occurs, the **change** to the coding of DNA is so **slight** it **does not affect** the **protein** being made. The proteins **appearance** and **function** are **unchanged.**

Occasionally **a mutation** does change the DNA code enough to result in an **altered protein** with a different shape.



Active site binds with the substrate.



Mutated active site has a different shape and no longer binds with the substrate.

The **active site** of an **enzyme** may have a **changed shape** and then the enzyme will **not** be able to **bind** to the **substrate**. The enzyme will no longer function.

Structural proteins such as **keratin** or **collagen** may also **lose** their **strength** if their shape was altered.

Inheritance part 1 – DNA structure (biology HT only)

Every cell in an organism (apart from a gamete) with a nucleus will have a **complete set** of **chromosomes**. This means cells possess every gene that is needed to make every protein the organism ever needs to produce.

Most cells in the body will only **use** a very **small amount** of the **genes** available. If a **gene is activated** to convert the DNA code into a certain protein then we say the **gene** has been **expressed**. A muscle cell will never be required to make the protein used in the iris of the eye. This gene will not be expressed in the muscle cell.

Most of the **DNA does not** actually **code for proteins**. Research is still ongoing to find out what the function of the non coding DNA is. Non coding parts can **switch genes on or off** in a cell. **Mutations** in the **non coding DNA** may **affect** how **genes** are **expressed**.

QuestionIT!

Inheritance
Part 1

- Reproduction
- Meiosis
- DNA and the genome

1. What is a gamete?
2. Name the male and female gametes in a) a human b) a daisy plant
3. For each row, tick **one** box to show which method of cell division is correct.

	Meiosis	Mitosis
Genetic mixing happens		
Gamete production occurs		
New cells show variation		
New cells have same number of chromosomes as parent		
Happens in skin cells		
Two divisions occur		
Two new cells are formed as a result		
Identical cells are formed		

4. How many chromosomes are found in the nucleus of a human:
   a) ovary cell ?
   b) egg cell ?
   c) embryo cell ?
   d) a cell just after fertilisation has occurred?
   e) a testes cell ?

5. Name the shape which best describes the DNA polymer.

6. How is DNA organised inside the cell nucleus?

7. Which is larger, a chromosome or a gene?

8. What does a gene code for?

9. Write down the definition of the genome of a horse.

10. List **two** reasons why it is important to understand more about the human genome.

Inheritance part 1 – QuestionIT (biology only)

11. What are three advantages of sexual reproduction?
12. What are three advantages of asexual reproduction?
13. List three organisms which reproduce using both sexual and asexual reproduction methods.
14. Where would you find a nucleotide?
15. What does a nucleotide consist of?
16. What are the symbols of the 4 bases found in DNA?
17. What does the code for an amino acid consist of?
18. Fill in the missing terms:
    The long strands of DNA are made of alternating _____ and _____ sections.
    Attached to each _____ is one of the four bases.
    The DNA polymer is made up of repeating _____ units.

Higher Tier biology only

19. In the complementary strands of DNA – which base is T always linked to?
20. Which organelle in the cytoplasm carries out protein synthesis?
21. What do carrier molecules bring to the organelle from the cytoplasm?
21. What happens in protein synthesis once the protein chain is complete?
22. What happens if a mutation codes for a slightly altered enzyme protein with a different shape?
23. What can non-coding parts of DNA do?

AnswerIT!

Inheritance
Part 1

- Reproduction
- Meiosis
- Advantages and disadvantages of sexual and asexual reproduction (biology only)
- DNA and the genome
- DNA structure (biology only)

1. What is a gamete?
   A cell with half the number of chromosomes of the parent cell.
2. Name the male and female gametes in a) a human b) a daisy plant
   a) Male = sperm Female = egg
   b) Male = pollen Female = egg
3. For each row, tick **one** box to show which method of cell division is correct.

	Meiosis	Mitosis
Genetic mixing happens	✓	
Gamete production occurs	✓	
New cells show variation	✓	
New cells have same no. of chromosomes as parent		✓
Happens in skin cells		✓
Two divisions occur	✓	
Two new cells are formed as a result		✓
Identical cells are formed		✓

4. How many chromosomes are found in the nucleus of a human:
   a) ovary cell ? ***46***
   b) egg cell ? ***23***
   c) embryo cell ? ***46***
   d) a cell just after fertilisation has occurred? ***46***
   e) a testes cell ? ***46***
5. Name the shape which best describes the DNA polymer.
   Double helix
6. How is DNA organised inside the cell nucleus?
   Arranged in chromosomes
7. Which is larger, a chromosome or a gene? ***Chromosome***
8. What does a gene code for? ***A particular sequence of amino acids***
9. Write down the definition of the genome of a horse.
   All the genetic material of the horse.
10. List **two** reasons why it is important to understand more about the human genome.
    To be able to identify the genes which are linked to different diseases
    To understand and be able to treat inherited disorders
    To use in tracing human migration patterns from the past.

Inheritance part 1 – AnswerIT (biology only)

11. What are three advantages of sexual reproduction?

Produce variation in the offspring

If environment changes can give a survival advantage meaning some organisms are likely to survive

Humans can speed up natural selection by selective breeding to increase food production

12. What are three advantages of asexual reproduction?

Only one parent needed

More time and energy efficient as do not need to find a mate

Faster than sexual reproduction

Many identical offspring can be produced when conditions are favourable

13. List three organisms which reproduce using both sexual and asexual reproduction.

Malarial parasites

Fungi

Strawberry plants

Daffodils

14. Where would you find a nucleotide? *DNA*
15. What does a nucleotide consist of? *Common sugar, phosphate group, base*
16. What are the symbols of the 4 bases found in DNA? *A T C G*
17. What does the code for an amino acid consist of? *A sequence of three bases*

Inheritance part 1 – AnswerIT (biology only)

18. Fill in the missing terms:
    The long strands of DNA are made of alternating __*sugar*___ and __*phosphate*____ sections.
    Attached to each __*sugar*____ is one of the four bases.
    The DNA polymer is made up of repeating _____*nucleotide*_____ units.

<u>Higher Tier biology only</u>

19. In the complementary strands of DNA – which base is T always linked to? ***A***
20. Which organelle in the cytoplasm carries out protein synthesis? ***Ribosome***
21. What do carrier molecules bring to the organelle from the cytoplasm? ***Amino acids***
21. What happens in protein synthesis once the protein chain is complete? ***The protein folds up into a unique shape.***
22. What happens if a mutation codes for a slightly altered enzyme protein with a different shape? ***The enzyme may no longer fit the substrate binding site***
23. What can non-coding parts of DNA do? ***Switch genes on or off and affect how genes are expressed.***

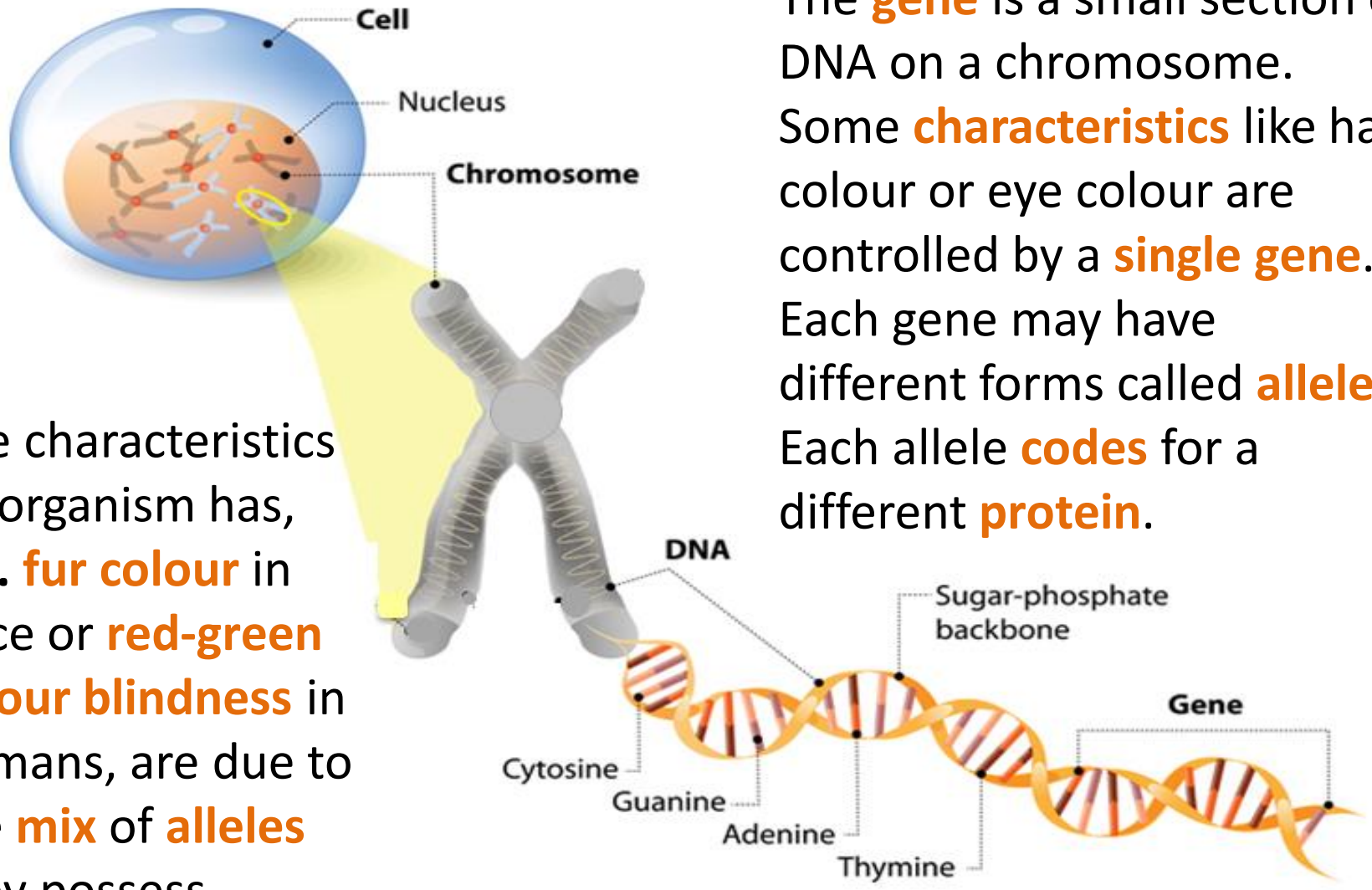
LearnIT!

KnowIT!

Inheritance, variation and evolution

Part 2

- Genetic Inheritance
- Inherited disorders
- Sex determination



The **gene** is a small section of DNA on a chromosome. Some **characteristics** like hair colour or eye colour are controlled by a **single gene**. Each gene may have different forms called **alleles**. Each allele **codes** for a different **protein**.

The characteristics an organism has, e.g. **fur colour** in mice or **red-green colour blindness** in humans, are due to the **mix** of **alleles** they possess.

Inheritance part 2 – Genetic Inheritance

Each gene has different forms of alleles. The alleles which are present are known as the **genotype**. These are often represented as letters such as **BB**. The genotype operates at a molecular level to develop the actual characteristics seen or the **phenotype**.

Most genes have two possible allele variations which are known as **dominant** or **recessive.**

Dominant alleles are represented by a **capital letter** e.g. B

Recessive alleles are represented by a **lower case letter** e.g. b

There are **3** possible combinations of alleles for each gene:

Two dominant alleles	**BB**
Two recessive alleles	**bb**
One dominant and one recessive allele	**Bb**

(always place the dominant allele first and do not use bB)

Inheritance part 2 – Genetic Inheritance

Homozygous

Homo means the same.
Two of the same alleles.
BB means homozygous dominant.
bb means homozygous recessive.

Genotype

This word describes the alleles which are present for a particular feature e.g. Bb.

You need to be able to use and explain these terms.

Phenotype

This word describes what can be physically seen - black fur, blonde hair, blue eyes.

Heterozygous

Hetero means different.
Two different alleles are present.
Bb means heterozygous.

Inheritance part 2 – Genetic Inheritance

In a particular species of mouse, the **dominant allele** operates at a molecular level to produce proteins that make the fur black. The **recessive allele** codes for white fur.

Phenotype = black fur
Genotype = ?
At least **one dominant** allele (B) is present because the mouse has black fur.
The mouse could be **genotype** BB **or** Bb.

KEY

Use B and b to represent the dominant and recessive alleles.
B = allele for black fur
b = allele for white fur

Phenotype = white fur
Genotype = bb
We know there are **no dominant** alleles present because the fur is white.

A recessive allele is only expressed if two copies are present and therefore no dominant allele present.

Inheritance part 2 – Genetic Inheritance

Genetic cross

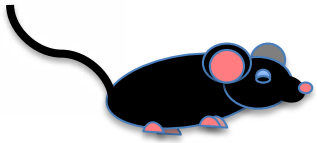
A **genetic cross** is a way of **modelling** the **potential outcome** from mating two parents where the **phenotype and genotype** are **usually known**. We use characteristics which are controlled by **a single gene** as it is easy to see the effect in the next generation and beyond.

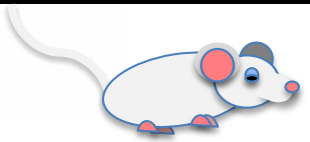
A typical exam question might ask:

A female mouse which was **homozygous dominant** for black fur was mated with a male mouse which was **homozygous recessive** for white fur.

What are the possible outcomes for fur colour for their offspring?

What do we know?





Parent phenotype:	Black fur	White fur
Parent genotype:	BB	bb

What gametes will be present?

in each egg	in each sperm
B B	b b

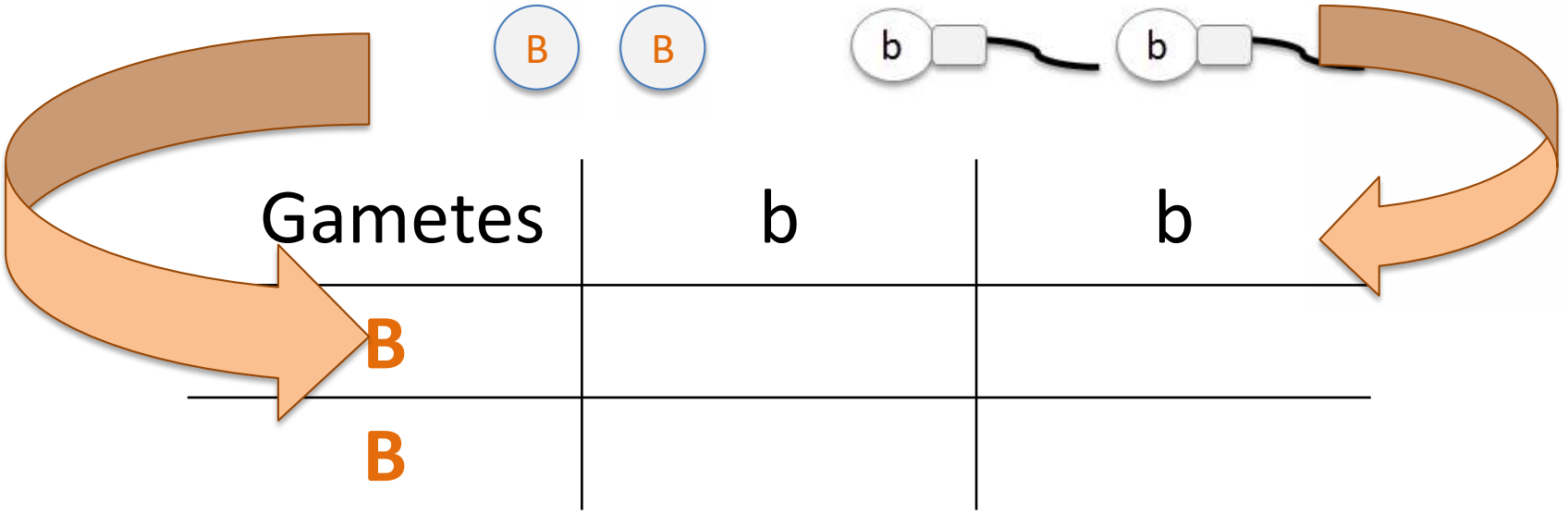
Inheritance part 2 – Genetic Inheritance

The Punnett Square

Reginald Punnett was a British geneticist who is most famous for creating the Punnett square diagram as a tool to predict the probability of genotypes in future offspring.

Parent phenotype: Black fur White fur

Parent genotype: BB bb



Inheritance part 2 – Genetic Inheritance

If an egg containing a dominant allele (B) is fertilised by a sperm with a recessive allele (b) then the result is an offspring with genotype Bb.

Gametes	b	b
B	Bb	Bb
B	Bb	Bb

The possible offspring all have the **genotype Bb**.
This is described as **heterozygous**.

The **phenotype** of all offspring from these parents will be **black fur** because one dominant allele is always present.

Inheritance part 2 – Genetic Inheritance

The **characteristic** of being a **tall** plant **or** a **short** pea plant is controlled by a **single gene**.
We will use the letter T to represent the gene for the purposes of a genetic diagram.
The allele which produces tall plants is **dominant** so we use **T**.
The allele for short plants is **recessive** so we use **t**.

Explain what would occur :

a) If two homozygous dominant plants were crossed.

The genotype for a homozygous tall plant is TT

Punnett square

Gamete	T	T
T	TT	TT
T	TT	TT

The genotype of **all** the future offspring will be TT and their phenotype will be **tall**. These parent plants will never produce short plants when crossed.

b) If two heterozygous plants were crossed.

The genotype for a heterozygous plant is Tt

Punnett square

Gamete	T	t
T	TT	Tt
t	Tt	tt

The **ratio** of **tall** plants to **short** plants likely to be produced is **3:1.**
In any four offspring, one would expect 1 homozygous dominant, 2 heterozygous and 1 homozygous recessive.

Inheritance part 2 – Genetic Inheritance

Explain what would occur :

c) If a homozygous dominant plant and a homozygous recessive plant were crossed.

The **genotype** for a homozygous dominant plant is TT.
The **genotype** for a homozygous recessive plant is tt.

Punnett square

Gamete	t	t
T	Tt	Tt
T	Tt	Tt

The genotype of **all** the future offspring will be Tt and their phenotype will be **tall**. All offspring will be heterozygous. The probability of getting a tall plant is described as 1 or 100%.

b) If two homozygous recessive plants were crossed.

The **genotype** for a homozygous recessive plant is tt.

Punnett square

Gamete	t	t
t	tt	tt
t	tt	tt

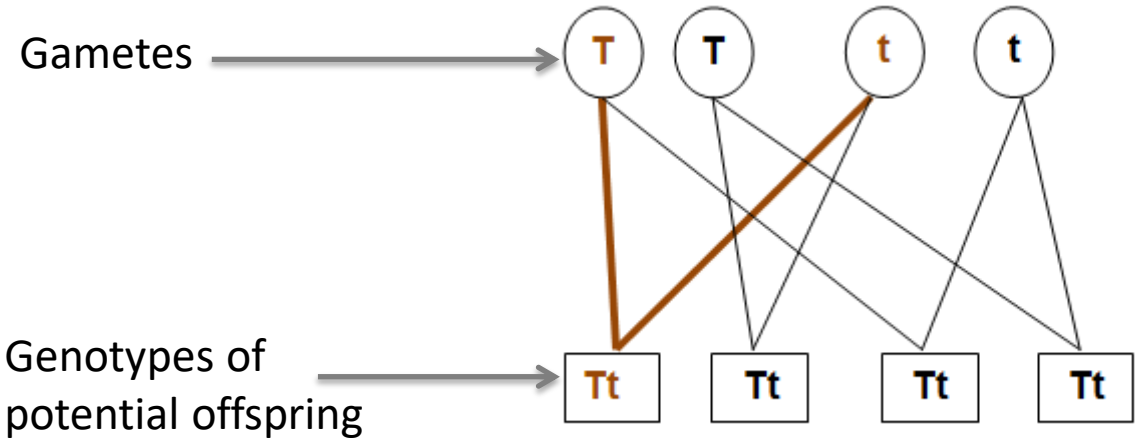
All future offspring will be **homozygous recessive**. Their **phenotype** will be **short.** These parents will **never** produce tall plants.

video

Inheritance part 2 – Genetic Inheritance

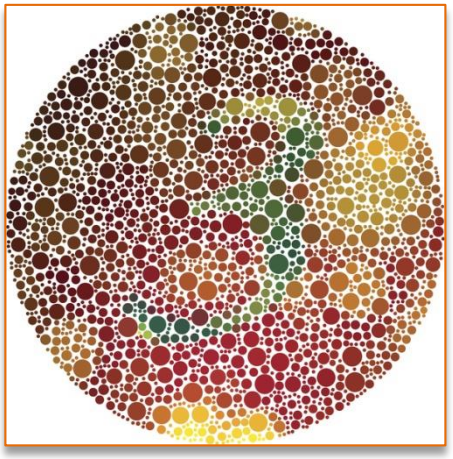
Not all exam questions use the Punnett square layout to find out possible genotypes. The basic principle is always the same.

A genetic diagram could also look like this:



Inheritance part 2 – Genetic Inheritance

Red green colour blindness in humans is also controlled by a single gene. It is a condition that a person is born with and is inherited from your parents. The gene is carried on the **X chromosome** and this means more **men** than women are affected.



The condition is caused by inheriting **two recessive alleles.**

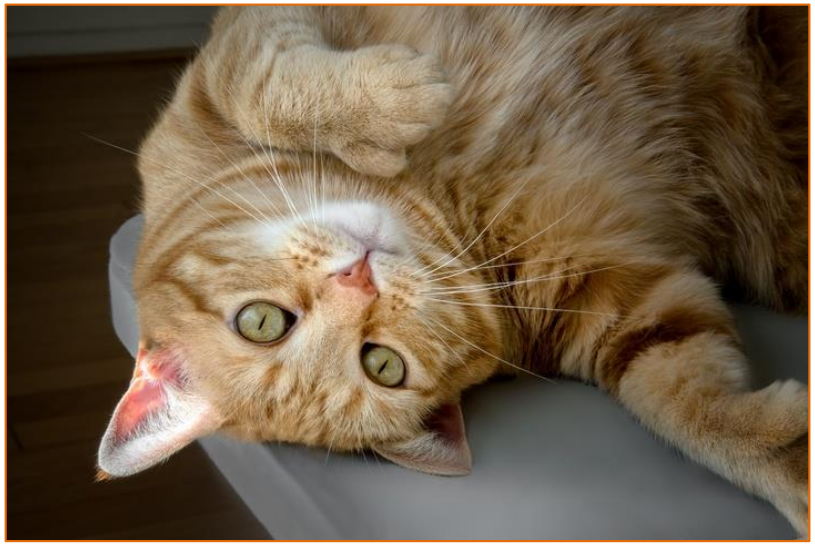
Human eye colour is an example of when **multiple** genes affect the phenotype.

However, **most characteristics** are a result of **multiple genes** interacting, rather than a single gene. These are called <u>polygenic</u> features (poly = many genic= gene).

We are able to describe a **phenotype <u>but</u> cannot write down a genotype** because more than one gene is involved.

Inheritance part 2 – Inherited disorders

Some **disorders** are inherited. They are caused by the **inheritance** of certain **alleles**.



A child born in India currently holds the record for the most digits with 7 digits on each hand and 10 on each foot.

What do you notice about this cat?

The cat has an extra digit.

Polydactyly is an inherited disorder caused by a **dominant allele**. This condition means **extra fingers or toes** are present.

As polydactyly is caused by a dominant allele, it can be passed on when only one parent has the disorder.

Inheritance part 2 – Inherited disorders

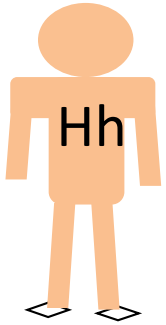
Cystic fibrosis is an inherited disorder caused by a **recessive** allele.
It affects **cell membranes** across the body.

H = healthy allele
h = CF allele

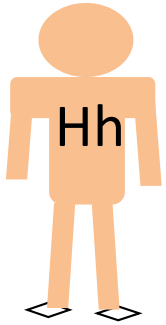
1 person **in** every **25** in the UK is statistically likely to be a **carrier** of **cystic fibrosis** (CF).

A **carrier** has **1 recessive allele** which codes for CF and **1 dominant allele** that codes for healthy cell membrane proteins.

A carrier is healthy and is unlikely to know they have the recessive allele unless they go through **screening** or have a child born with CF.



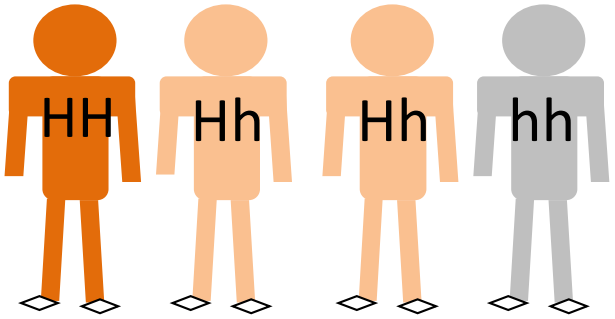
carrier father



carrier mother

Gamete	H	h
H	HH	Hh
h	Hh	hh

Possible offspring



If **two carriers** become parents there is a **1 in 4 chance** of their child having **cystic fibrosis**. This can also be described as **25% or 0.25.**

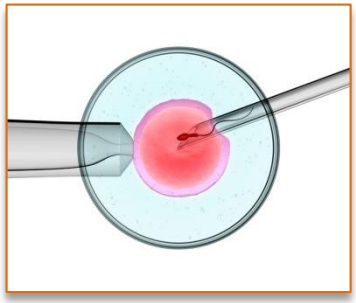
There is a **3 in 4 chance** of having a **healthy child**. This can be described as **75% or 0.75.**

There is a **1 in 2** chance of having a **healthy child** who **carries** the **recessive allele**. This can also be described as 50% or 0.5.

Inheritance part 2 – Inherited disorders

It is thought that 1 in 2500 babies born in the UK each year will have cystic fibrosis.

Screening of the embryo (or fetus) can be completed from 10 weeks of pregnancy. There is a **risk** of miscarriage with this process.
A fine needle is passed through the abdomen into the uterus and a small piece of the developing placenta is removed. This is analysed to see if alleles that cause polydactyly, cystic fibrosis or other genetic disorders are present. This testing is usually only done when there is a family history of the disorder. **Screening is costly** and **not 100% reliable**.



Embryos can be screened for parents undergoing **IVF** (in vitro fertilisation). The egg and sperm are mixed and fertilisation occurs in a laboratory. Usually several embryos are produced. The embryos are then screened. Any embryos which have the **faulty alleles** are **not implanted** into the mothers uterus. Only healthy babies will be born.

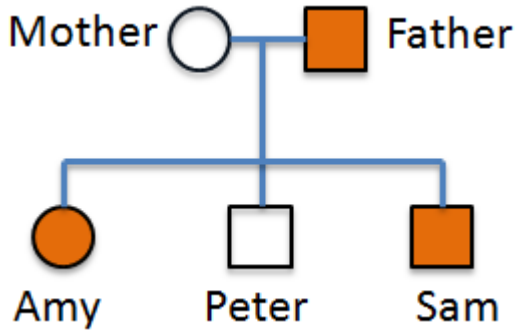
Gene therapy may be suggested for some disorders. This means **replacing** the **faulty allele** with a normal allele. This can not be done to gametes so can only occur in an individual who already has inherited the disorder. Gene therapy is still being researched and is not always successful. It is also **expensive**. Video

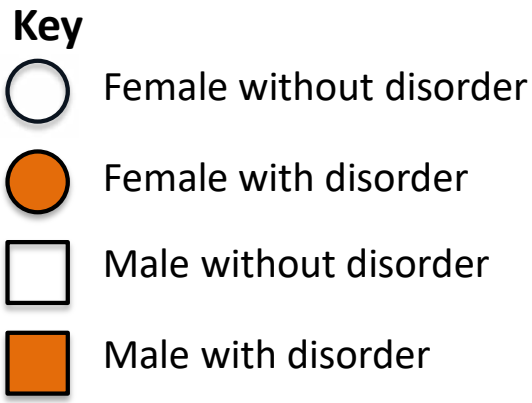
Gene therapy and embryo screening can be used to **alleviate suffering** but it is important to consider the **ethical issues** of these techniques.

Inheritance part 2 – Inherited disorders

A **family tree** can help to show how **genetic disorders** are inherited in a family. They can be used to work out the **probability** that a member of the family will **inherit** a disorder.
Read the **key** carefully to help you interpret a family tree accurately.

The family tree below shows the inheritance of a disorder caused by a **dominant** allele.





What is the genotype of the mother? **Homozygous recessive**
What is the genotype of the father? **Heterozygous**

If the father was **homozygous dominant** then **all** the **offspring** would have the disorder. Peter does not have the disorder and is **homozygous recessive.**

Inheritance part 2 – Inherited disorders

Genetic testing can give answers to a question linked to science such as:

- What is the risk of my child having cystic fibrosis?

Genetic testing cannot give answers to questions linked to economic, social or ethical issues such as:

- *Should I have a genetic test because it may cause a miscarriage?*
- *If the embryo has a disorder should I have an abortion?*
- *Is it right that only healthy embryos are implanted in IVF?*
- *Should screening be available to everyone, not just those who can afford it or have the disorder in their family history?*
- *What if the test result is wrong?*

Different people will have different views.

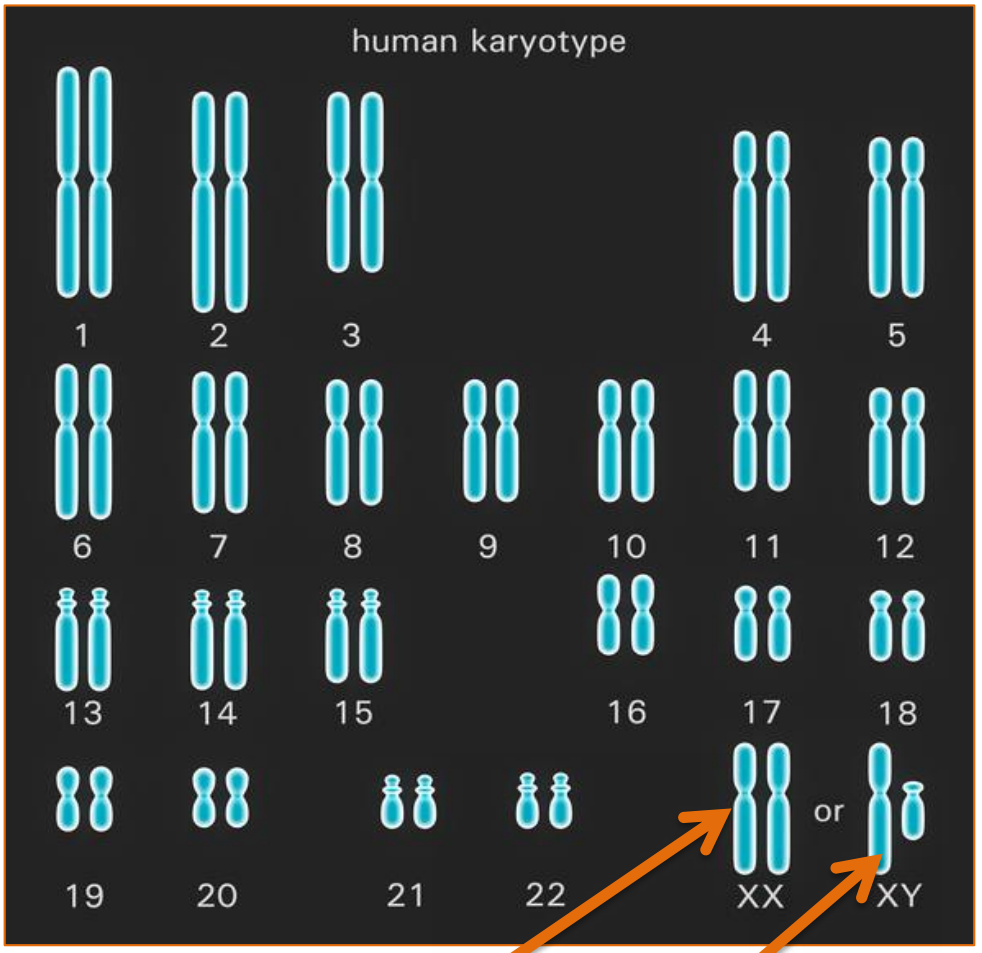
You will need to make informed decisions about the economic, social and ethical issues concerning embryo screening.

Inheritance part 2 – Sex determination

An ordinary **human body cell** contains **23 pairs** of chromosomes.
One chromosome of each pair comes from the egg and one from the sperm.

22 pairs of chromosomes control characteristics.

The **23rd pair** of chromosomes are called **sex chromosomes**. This pair carry the genes that determine sex. The sex chromosomes are **not identical** to each other and so are called **X** and **Y.**



In **females** the sex chromosomes are the same **-XX**

In **males** the sex chromosomes are different-**XY**

Inheritance part 2 – Sex determination

How is sex inherited?

The 23rd pair of chromosomes are responsible for determining the sex of a human.

The **Punnett square** is used to show the chances of an offspring being male or female.

A **woman** has the **genotype XX** and a **man** has the **genotype XY**.

Gametes	X	X
X	XX	XX
Y	XY	XY

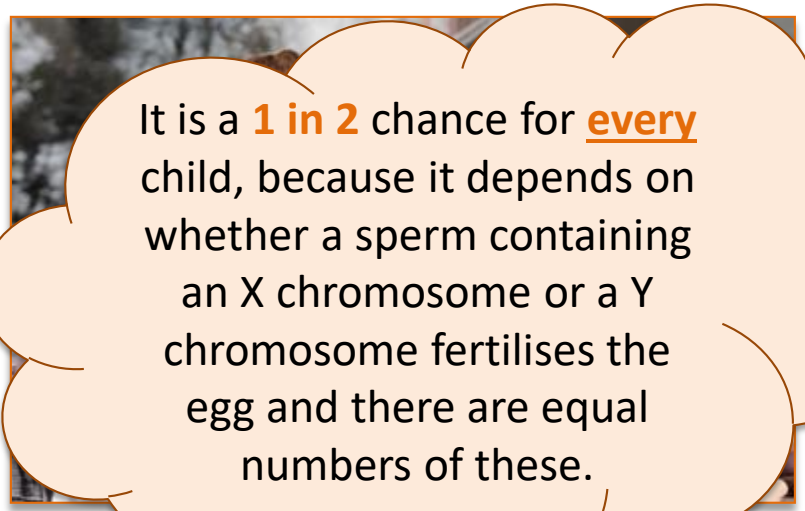
There is a **1 in 2** chance of the offspring being male or female.

This can also be described as a ratio of **1:1, 50:50** or **50%** or **0.5** of being male or female.

Inheritance part 2 – Sex determination

A man and woman have three children – all boys. The woman is pregnant with their fourth child.

What is the chance of the next child being a girl?



It is a **1 in 2** chance for **every** child, because it depends on whether a sperm containing an X chromosome or a Y chromosome fertilises the egg and there are equal numbers of these.

I think it is more likely to be a girl as they already have 3 boys .

I think there is **more chance** of the new baby being a boy because they **have 3 boys already**.

QuestionIT!

Inheritance, variation and evolution Part 2

- Genetic Inheritance
- Inherited disorders
- Sex determination

Inheritance part 2 – QuestionIT

1. Complete the sentences below using one of the following words:

genotype *phenotype* *homozygous* *gamete* *chromosome*

The same alleles for a particular characteristic are described as .....
Mice fur can be described by its colour. This is known as the .....
The alleles for a particular characteristic determine its .....
The pollen of a rose plant can also be described as a male .....

2. What are the different forms of a gene called ?

3. Why is it easy to describe an organisms phenotype for a particular characteristic but very difficult to state the genotype?

4. List the alternative ways of describing the following outcome of a genetic cross:

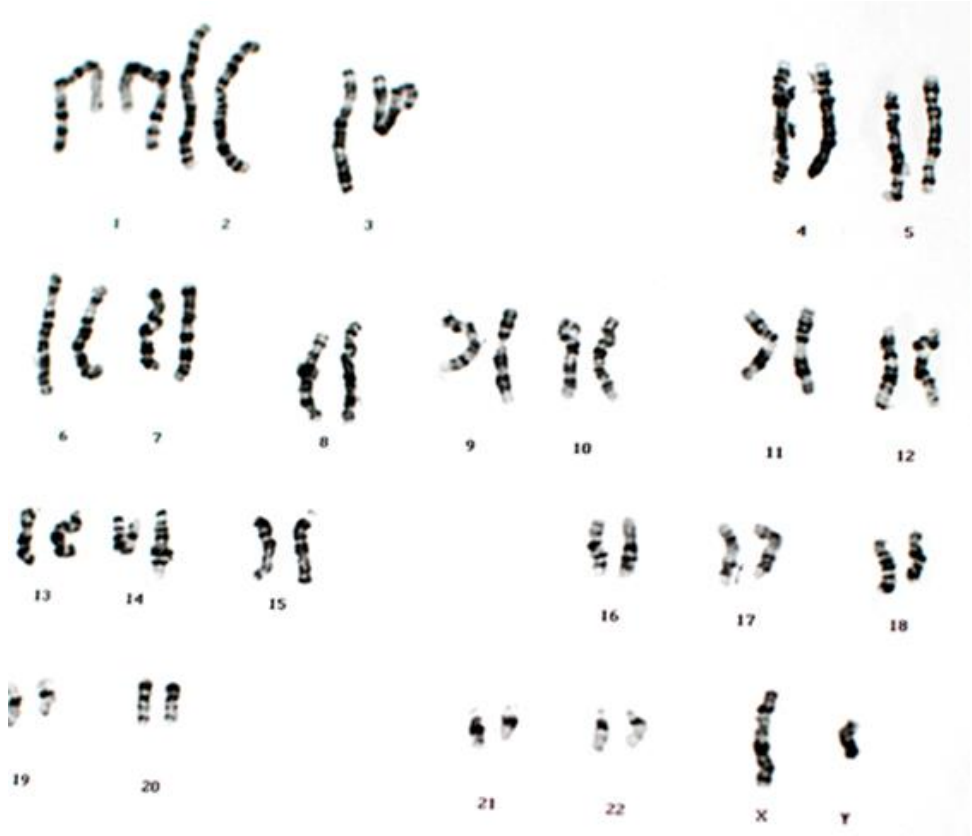
3 in every 4 crosses will have black fur.

5. If two heterozygous tall plants were crossed 75 times, what proportion of the offspring would you expect to be short?

6. What is polydactyly and is it caused by inheriting a recessive or dominant allele?

Look at the following picture of a persons chromosomes.

7. How many chromosomes does this person have in a normal body cell?
8. What sex is the person and how do you know?



9. Black fur is dominant to brown fur in mice.
Use B to represent black fur and b to represent brown fur.

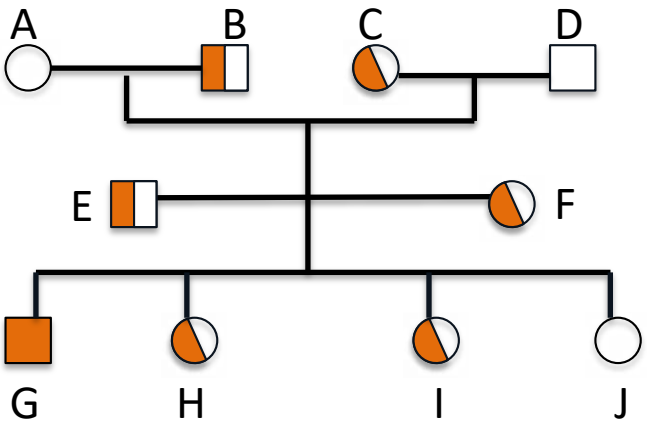
a) Complete the Punnett square diagram to show the outcome of a genetic cross between two heterozygous mice.

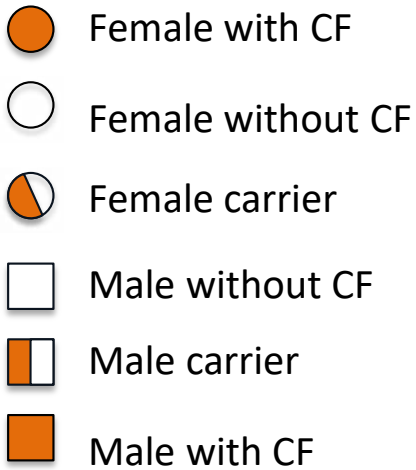
Gametes		

b) What is the phenotype of the parent mice?
c) What are the chances of a homozygous recessive mouse being born to two heterozygous mice?

10. Is someone who is heterozygous for cystic fibrosis healthy?

11. The family tree shows the inheritance of cystic fibrosis (CF). Cystic fibrosis is a condition caused by a recessive allele. Let F = healthy allele and f = CF allele





a) What is the genotype of a female carrier?
b) Explain why person G inherited cystic fibrosis.
c) Explain why person J did not inherit cystic fibrosis.
d) What is the probability of a fifth child having cystic fibrosis?
e) Many people feel opposed to the screening of embryos to identify the CF allele. Suggest **two** reasons why they may feel this way.

Higher tier questions

12. The flower colour for pea plants is controlled by a single gene. Red flowers are dominant to white flowers.

A homozygous dominant plant and a heterozygous plant are crossed to produce offspring.

a) What is the phenotype of the homozygous dominant plant?

b) Draw a genetic diagram to show all the possible arrangements of alleles in the offspring.

c) What is the chance of producing homozygous dominant red flowering plants?

AnswerIT!

Inheritance, variation and evolution
Part 2

- Genetic Inheritance
- Inherited disorders
- Sex determination

Inheritance part 2 – AnswerIT

1. Complete the sentences below using one of the following words:

   genotype phenotype homozygous gamete chromosome

   The same alleles for a particular characteristic are described as ***homozygous***
   Mice fur can be described by its colour. This is known as the ***phenotype***
   The alleles for a particular characteristic determine its ***genotype***
   The pollen of a rose plant can also be described as a male ***gamete***

2. What are the different forms of a gene called ?

   Alleles

3. Why is it easy to describe an organisms phenotype for a particular characteristic but very difficult to state the genotype?

   Most characteristics are a result of multiple genes interacting .

4. List the alternative ways of describing the following outcome of a genetic cross:

   3 in every 4 crosses will have black fur.

   75% 0.75 3/4

5. If two heterozygous tall plants were crossed 75 times, what proportion of the offspring would you expect to be short?

   25% or 19

6. What is polydactyly and is it caused by inheriting a recessive or dominant allele?

   A genetic disorder which results in having extra fingers or toes - dominant allele

Look at the following picture of a persons chromosomes.

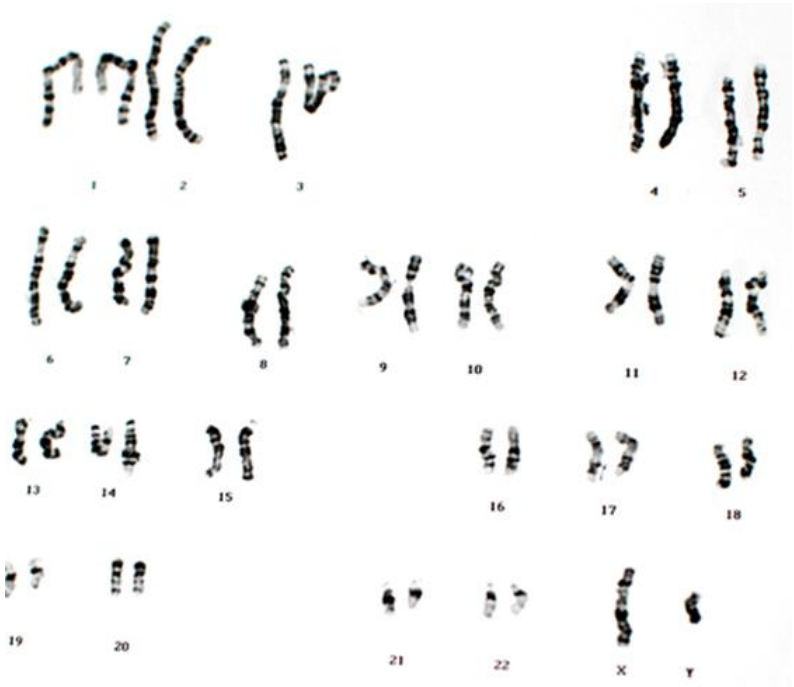
7. How many chromosomes does this person have in a normal body cell?

23 pairs or 46

8. What sex is the person and how do you know?

A male

Because the sex chromosomes are different (XY)



9. Black fur is dominant to brown fur in mice.

Use B to represent black fur and b to represent brown fur.

a) Complete the Punnett square diagram to show the outcome of a genetic cross between two heterozygous mice.

Gametes	*B*	*b*
B	*BB*	*Bb*
b	*Bb*	*bb*

b) What is the phenotype of the parent mice?

Black fur

c) What are the chances of a homozygous recessive mouse being born to two heterozygous mice?

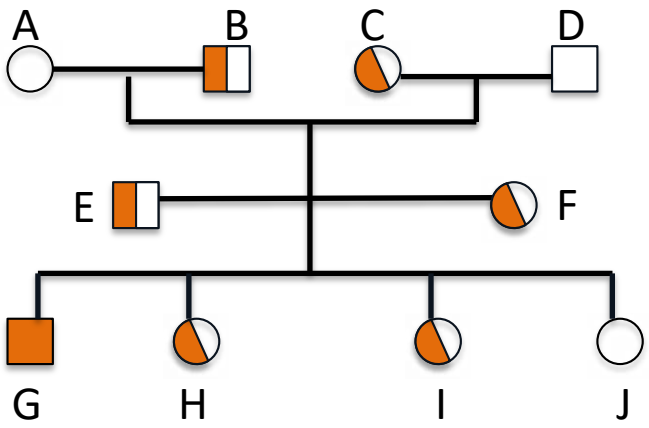
1 in 4 or 25% or 0.25

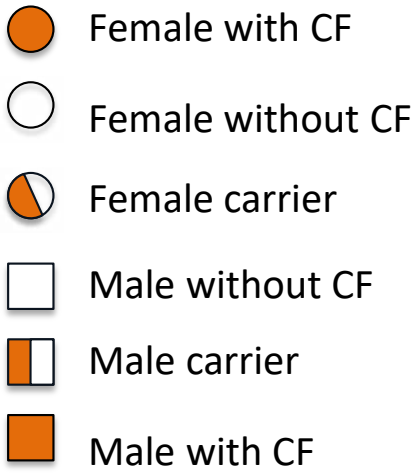
10. Is someone who is heterozygous for cystic fibrosis healthy?

Yes, they are a carrier but do not suffer from CF themselves

Inheritance part 2 –AnswerIT

11. The family tree shows the inheritance of cystic fibrosis (CF). Cystic fibrosis is a condition caused by a recessive allele. Let F = healthy allele and f = CF allele





a) What is the genotype of a female carrier? ***Ff***

b) Explain why person G inherited cystic fibrosis

Inherited a recessive allele from both E and F.

As no dominant allele present, the CF alleles code for faulty cell membranes

c) Explain why person J did not inherit cystic fibrosis.

Inherited two dominant alleles from E and F

d) What is the probability of E and F having a fifth child with cystic fibrosis?

1 in 4, 25%, 0.25, 1:3 or ¼

e) Many people feel opposed to the screening of embryos to identify the CF allele. Suggest **two** reasons why they may feel this way.

Screening procedure may cause miscarriage or damage embryo/fetus
The embryo has a right to life
Screening is expensive and could be used for other purposes
Have to make moral/ethical or religious decisions as a result such as whether to terminate.

Inheritance part 2 – AnswerIT (HT only)

Higher tier question

12. The flower colour for pea plants is controlled by a single gene. Red flowers are dominant to white flowers.
    A homozygous dominant plant and a heterozygous plant are crossed to produce offspring.
    Let R represent the dominant allele.

a) What is the phenotype of the homozygous dominant plant?

Red flowers

b) Draw a genetic diagram to show all the possible arrangements of alleles in the offspring.

Gamete	*R*	*r*
R	*RR*	*Rr*
R	*RR*	*Rr*

c) What is the chance of producing homozygous dominant red flowering plants?

1 in 2 50:50 50% or ½ or 1:1

LearnIT!
KnowIT!

Inheritance, variation and evolution
Part 3

- Variation
- Evolution
- Selective Breeding
- Genetic Engineering
- Cloning (biology only)

Inheritance part 3 – Variation

Variation means that individuals in a population show **differences** in characteristics. Population is the number of one species in a habitat. The **genome** and its **interaction** with **the environment** influence the development of a **phenotype** in an organism.

Variation within a population of a species is usually extensive.

Causes of variation may be:

❑ **differences** in the **genes** individuals have inherited due to mutation, meiosis and sexual reproduction.

❑ **differences** in the **environmental** conditions in which individuals have developed.

❑ or a **combination** of both genetic and environmental causes.

Inheritance part 3 – Variation

Identical twins are produced from the same egg and sperm. They show very little or no genetic variation. One twin has a scar and this is environmental variation.

Factors which are **influenced** by **both genetic and environmental** variation are:
skin colour (can be tanned),
weight (can be affected by food availability),
being athletic.

Human phenotypes which are caused by **genetic variation** are:
Eye colour
Natural hair colour
Nose shape
Ear lobe shape
Blood group

Human phenotypes influenced by the **environment** are:
Hair length
Accents
Tattoos
Scars
Language spoken

Inheritance part 3 – Variation

All **genetic variations** arise from **mutations**.

A mutation is a change in the DNA sequence of an organism. **Mutations** are occurring **continuously** during cell division. **Most** mutations **do not alter** the **phenotype.** Some will influence the phenotype, but very few mutations actually determine the phenotype.

If a **new phenotype** is **suited** to an environmental change, it can **lead** to a relatively **rapid change** in the **species**. An example is seen below:

The peppered moth is camouflaged against tree bark. Birds cannot see it easily. The peppered moth lives long enough to breed and pass on its genetic information. This phenotype is found mainly in the countryside now.

During the industrial revolution, tree bark and buildings in cities and towns became blackened. The peppered moth became easy prey for the birds. A mutation occurred which changed the colour of the moth to black. The black phenotype is now found in large numbers in cities.

Inheritance part 3 – Evolution

Evolution is a **change** in the inherited characteristics of a population **over time**. This occurs through a process called **natural selection** which may result in a new species being formed.

The **theory of evolution** by natural selection states that all living things have evolved from **simple life forms** that developed over **3 billion years ago.**

Species is defined as a group of similar looking individuals which can breed and produce fertile offspring.

The **differences** in a population gives some individuals an **advantage**. An individual may be more resistant to a disease, or better camouflaged, or stronger, faster or better able to attract a mate. This individual is more likely to **survive for longer** and be able to breed to **pass on** desirable genes. Nature is selecting the individual with the **phenotypes** most suited to survival. This is called **natural selection.**

Inheritance part 3 – Selective breeding

Selective breeding is also called artificial selection. Selective breeding is where **humans breed plants** and **animals** for particular **chosen genetic characteristics** which are either **useful** or **for appearance.**

1
- Parents chosen from a mixed population of variants
- Parents are bred together

2
- Offspring chosen with the desired characteristics
- They are bred together

3
- Offspring chosen from next generation with desired characteristics are bred together. This continues for many generations until all offspring have the desired characteristics.

video:

Inheritance part 3 – Selective breeding

Why do humans use selective breeding?

To produce plants with large or unusual flower shapes or colours

To produce animals with more meat or milk

To produce crops with better yields or disease resistance

To produce domestic dogs with a gentle nature

Inheritance part 3 – Selective breeding

Selective breeding reduces variation and can lead to "inbreeding". The population will have the same strengths but also the same weaknesses. **Infectious diseases** are more likely to **spread** through a genetically similar population because of this vulnerability.
Some breeds are **particularly prone** to **disease** or **inherited defects** as a result of **inbreeding**.

The standards set for a **pedigree Pug** are :

- Large dark eyes
- Ears must be small and thin
- Muzzle must be short and square.
- Head is large with no indentations.
- Wrinkles must be large and deep.

In order to maintain this standard breeders often **mate closely related dogs** with good characteristics together.
A pedigree pug can be a result of **5-6 generations of inbreeding.**

Often puppies which do not meet the standards are killed illegally.
Many pugs will go on to develop **painful crippling conditions:**

- Chronic hip/ knee joint problems
- Severe breathing issues due to a deformed nose and short trachea
- Chronic eye problems due to the wrinkles around the eye folding in and scratching the cornea.
- Skin irritation due to bacteria infections in the deep wrinkles.

Inheritance part 3 – Genetic Engineering

Genetic engineering is a process which involves **modifying the genome** of an organism by **introducing** a **gene** from **another organism** to give a desired characteristic.

Plant crops have been genetically engineered to be **resistant** to diseases, or be resistant to insect attack, resistant to herbicides or to produce bigger better fruits. These are known as **genetically modified** or **GM** crops. GM crops usually show an **increased yield**.

A **herbicide** is a chemical which **kills plants** (also called a weed-killer). If a crop plant is resistant to herbicide, the farmer can spray herbicide to kill all other plants in the field without affecting the crop.
Plants resistant to insect attack have been **modified** to produce their own pesticide.

All our food from plants and animals contains genes. A plant cell contains about 30 000 genes. GM involves adding about 1-10 extra genes. Video:

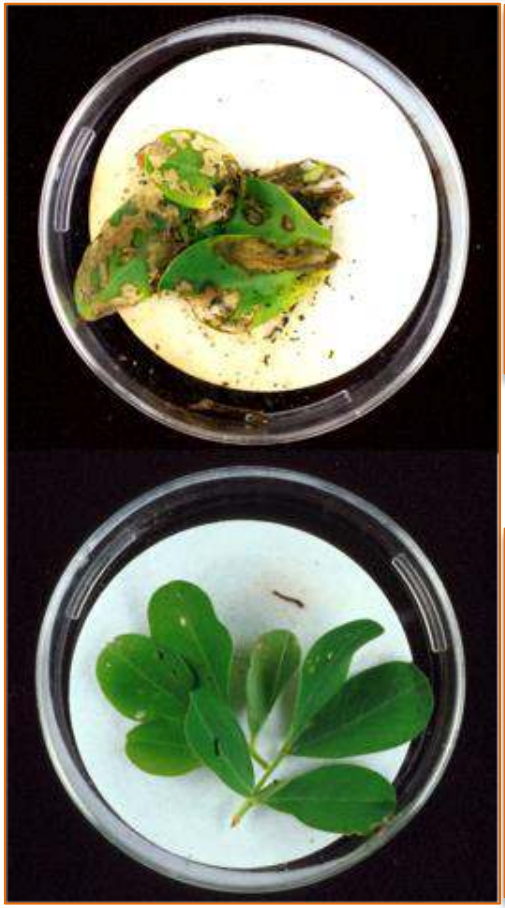
Inheritance part 3 – Genetic Engineering

In **genetic engineering, genes from** the chromosomes of **humans** and other organisms are **cut out** of the **DNA** using **enzymes**. The **genes** are then **transferred** to the **cells of the organism** to be genetically modified.

A bacteria called *Bacillus thuringiensis* lives in the soil. It produces a toxin that kills a variety of common insect pests.

The **gene** which produces the toxin in the bacteria has been **isolated** and **transferred** to the crop **plant's genome**.

The crop **plant** now **produces** the **toxin** and insects which eat it are poisoned. This means there are **less insects** to eat the crop and so a **bigger yield** is produced. The farmer does not have to spray the crop with pesticide either so it makes **economic** sense as well.



Plant **not** genetically modified with the toxin producing gene.

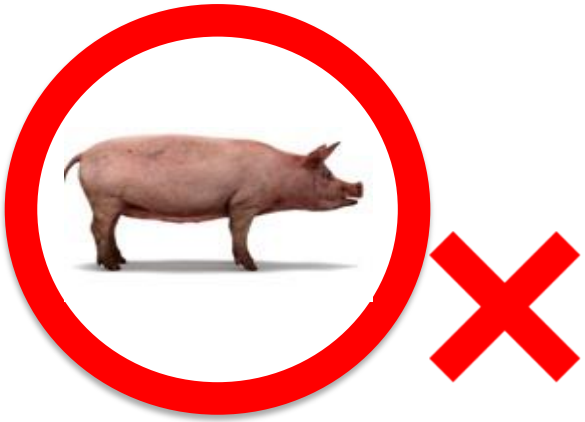
Plant which **is genetically modified** with the toxin producing gene.

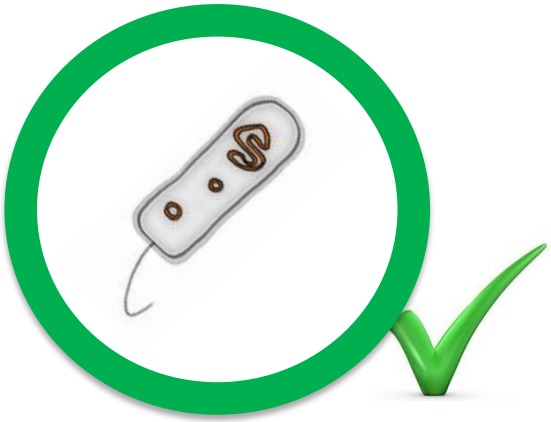
Inheritance part 3 – Genetic Engineering

Insulin is a naturally occurring hormone produced in the pancreas. In diabetes, a fault in the pancreas means insulin is not made effectively.

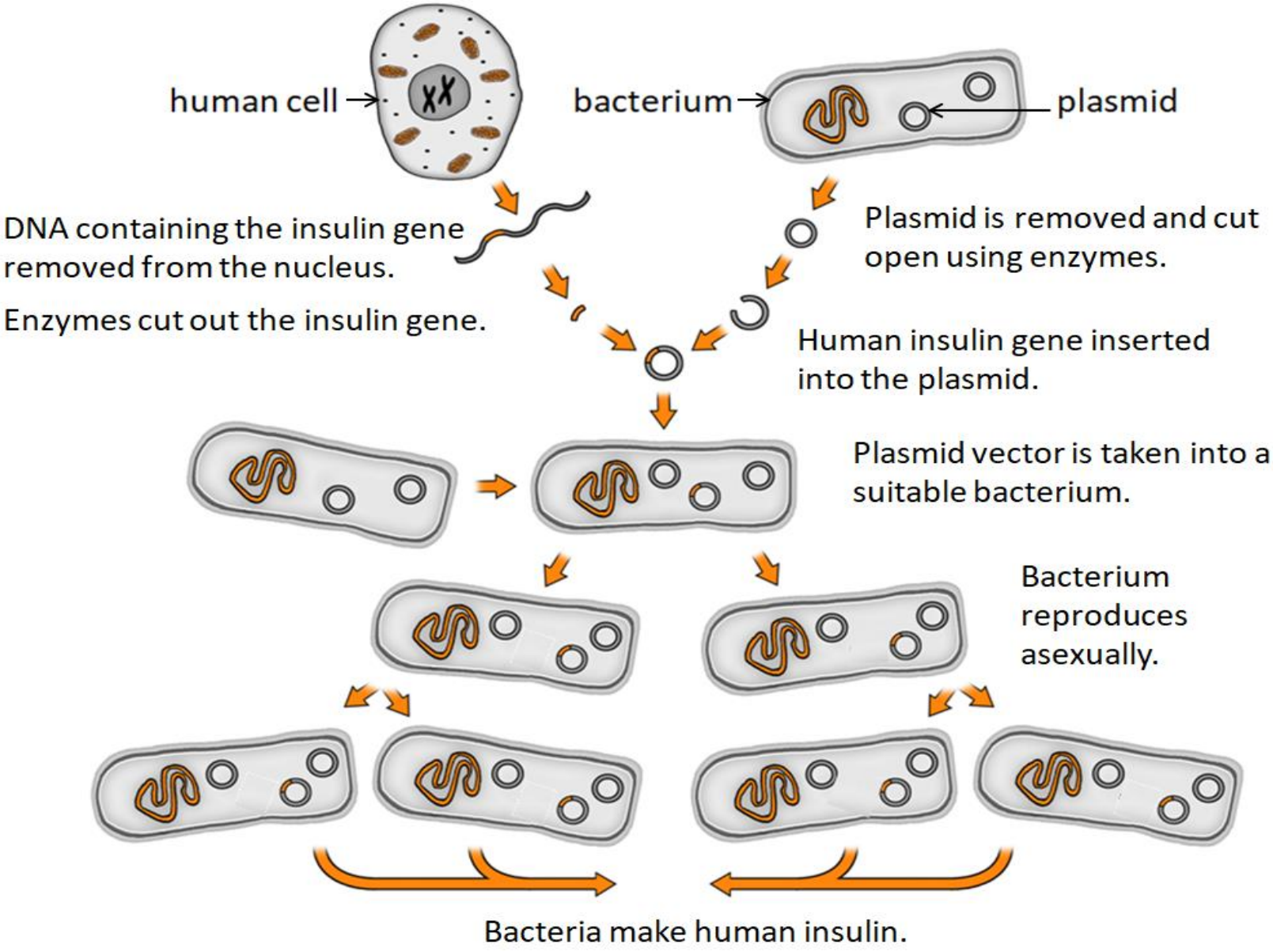
Diabetics can inject themselves with insulin. The insulin for injections used to be collected from a pig's pancreas. Some diabetics had severe allergic reactions to pig insulin because it was not the same as human insulin.

Genetic engineering is now used to **produce 'human insulin'** from **genetically modified bacteria**. It is cheaper, safer and more ethically acceptable than using specially bred pigs which had to be killed.





Inheritance part 3 – Genetic Engineering HT only



Inheritance part 3 – Genetic Engineering

Genetic engineering is a new technology that can be **very useful** but there are also **ethical issues** to consider.

Some benefits of Genetic Modification

Bigger crop yields so more food can be produced. This might solve the world food shortage in the future.

Human insulin can be **mass produced** by **genetically engineered bacteria** meaning pigs do not have to be slaughtered and costs are reduced. **Allergic reactions** are reduced.

Medical research is exploring the possibility of **genetic modification** to **overcome** some **inherited disorders.**

Some concerns regarding Genetic modification

We **do not know the effect** of growing **GM crops** on nearby **populations** of **wild flowers** and **insects**.

GM crops which **produce their own pesticide** may **kill insects** which are needed to **pollinate** other plants.

Some people feel that the **effects** of **eating GM** crops on **human health** have not been fully explored.

Should humans be inserting genes from one organism into a totally different organism?

video

Inheritance part 3 – Cloning (biology only)

Offspring which have been produced by **asexual reproduction** are genetically **identical** to the parent and each other. They are called **clones**.

Animal and plant cells are often **cloned** because they possess a **characteristic** which is **desirable,** such as **resistance to disease**.

Tissue Culture is one method of cloning plants. A **small piece of tissue** is taken from a **plant** and grown on agar which contains the right balance of nutrients and plant hormones. It can be more **expensive** but can produce hundreds of identical plants. This method is often used to **preserve rare plants** or **commercially** in nurseries.

Cuttings: This method has been used for a long time by gardeners. It is **simple** and **cheap** to do. A part of the plant is removed and placed in moist soil. If the conditions are suitable the plant piece will grow as a new plant.

Inheritance part 3 – Cloning (biology only)

Cloning in **animals** is also gaining in importance economically.
Normal reproduction can be slow and a cow with desirable characteristics will only produce 1 or 2 calves a year. A cow may produce 8 calves in her life.

Cloning can speed up the process of developing a herd of cows with desirable characteristics by using **embryo transplants**. It is **expensive** and some people feel it is **unethical** to remove the embryo from its mothers uterus and split it apart.

The process is:

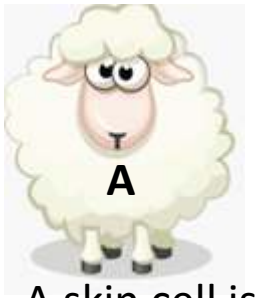
- The cow becomes **pregnant**.
- The developing **embryo is removed** early in pregnancy **before cells** become **specialised**.
- The cells are **split apart** and grown in laboratory conditions for a time.
- The new **embryos** are then **transplanted** into lots of different **host** cows.

The initial cow may now be responsible for producing over 30 calves a year with desirable characteristics. Farmers can **sell embryos** across the world.

Inheritance part 3 – cloning (biology only)

Another method of cloning in animals is **adult cell cloning**.

Dolly the sheep was the first animal to be successfully cloned. It took 277 attempts before Dolly was born.



A skin cell is taken from Sheep A.

Unfertilised egg cell is taken from Sheep B.

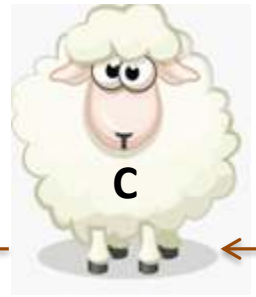
Nucleus is removed.

Nucleus is removed.

Nucleus from sheep A is fused with empty egg cell of sheep B.

An electric shock stimulates the egg cell to divide.

Embryo is implanted into a adult female sheep C to continue its development.



A clone of sheep A is born.

QuestionIT!

Inheritance, variation and evolution

Part 3

- Variation
- Evolution
- Selective Breeding
- Genetic Engineering

Inheritance part 3 – QuestionIT

1. What does variation mean?
2. Complete the table to indicate the likely cause of variation in phenotypes for the following characteristics:

	Eye shape	Gender	Blood group	Ear lobe shape	Weight	Freckles
Genetic	✓					
Environmental						
Both						

3. Write a definition for evolution.
4. What does the theory of evolution by natural selection state?
5. What is the definition of the term species?
6. Humans choose animals or plants to breed from based on usefulness or appearance. List **four** characteristics which would be selected for e.g. a thick woolly coat in sheep (two in plants and two in animals).
7. What is a major disadvantage caused by selective breeding?
8. How often do mutations occur?
9. How likely is it that a mutation will lead to a new phenotype?

Inheritance part 3 – QuestionIT

10. What is genetic engineering?
11. What human product is made by genetically engineered bacteria to treat diabetes?
12. What are plants called which have had their genome modified?

Higher tier only

13. How are the required genes isolated from the host?
14. What is the biological definition of a vector ?
15. Name a common vector for inserting genes into the required cells.
16. When in the life cycle must genes be transferred to the cells of animals, plants or microorganisms?
17. List three reasons which people are concerned about in relation to genetic engineering

Biology questions

18. What is tissue culture?
19. Why is tissue culture important?
20. Why is an electric shock used in adult cell cloning?
21. What is the term used to describe the technique gardeners use to produce many identical new plants from a parent plant?

AnswerIT!

Inheritance, variation and evolution Part 3

- Variation
- Evolution
- Selective Breeding
- Genetic Engineering

Inheritance part 3 – AnswerIT

1. What does variation mean?
   Variation means the differences in the characteristics of individuals in a population.
2. Complete the table to indicate the cause of variation in phenotypes for the following characteristics:

	Eye shape	Gender	Blood group	Ear lobe shape	Weight	Freckles
Genetic	✓	✓	✓	✓		
Environmental						
Both					✓	✓

3. Write a definition for evolution.
   A change in the inherited characteristics of a population over time, through a process of natural selection.
4. What does the theory of evolution by natural selection state?
   All species of living things have evolved from simple life forms that first developed more than 3 billion years ago.
5. What is the definition of the term species?
   A group of similar looking individuals who can breed together and produce fertile offspring.

Inheritance part 3 – AnswerIT

6. Humans choose animals or plants to breed from based on usefulness or appearance. List **four** characteristics which would be selected (two in plants and two in animals).
   Disease resistance in crop plants
   Animals which produce more meat or milk
   Domestic dogs with a gentle nature
   Large or unusual flowers
7. What is a major disadvantage caused by selective breeding?
   can lead to inbreeding where some breeds are particularly prone to disease or inherited defects
8. How often do mutations occur?
   Continuously
9. How likely is it that a mutation will lead to a new phenotype? ***Very rare***

10. What is genetic engineering? ***A process which involves modifying the genome of an organism by introducing a gene from another organism to give a desired characteristic.***

11. What human product is made by genetically engineered bacteria to treat diabetes?
    Insulin
12. What are plants more commonly called when they have had their genome modified?
    GM crops

Higher tier only

13. How are the required genes isolated from the host? *Using an enzyme*
14. What is the role of a vector in genetic engineering? *Used to insert the gene into the required cells*
15. Name a common vector used in genetic engineering. *Bacterial plasmid / virus*
16. When in the life cycle must genes be transferred to the cells of animals, plants or microorganisms? *Early on in development so the new cells develop with the desired characteristic*
17. List three reasons which people are concerned about in relation to genetic engineering
    Do not know the effect of using GM crops on populations of wild flowers and insects. *may kill insects which are needed to pollinate other plants.*
    Some people feel that the effects of eating GM crops on human health have not been fully explored.
    For ethical reasons - should humans be inserting genes from one organism into a totally different organism?

Biology questions

18. What is tissue culture? ***Using small groups of cells from a part of a plant to grow identical new plants.***
19. Why is tissue culture important? ***To preserve rare plant species***
    Commercially in nurseries to grow lots of new identical plants
20. Why is an electric shock used in adult cell cloning? ***To stimulate the egg cell to divide and form an embryo***
21. What is the term used to describe the technique gardeners use to produce many identical new plants from a parent plant? ***Taking a cutting***

LearnIT!

KnowIT!

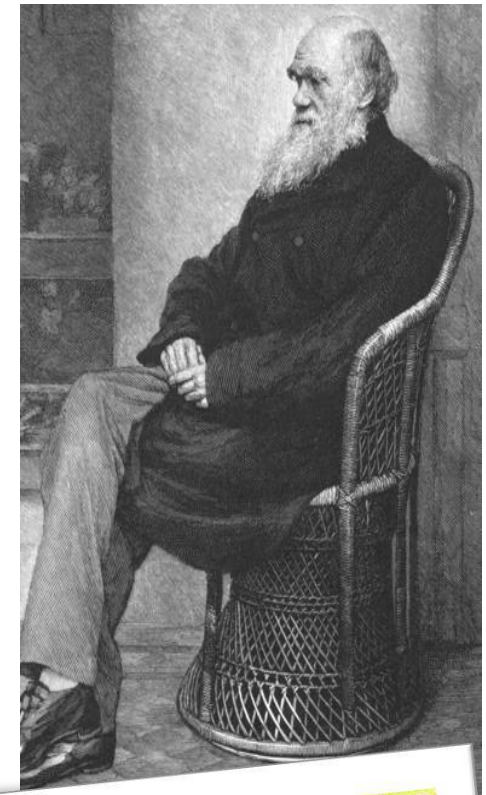
Inheritance, variation & evolution

Part 4

- Theory of evolution (biology only)
- Speciation (biology only)
- Understanding of genetics (biology only)
- Evidence for evolution
- Fossils
- Extinction
- Resistant bacteria
- Classification of living organisms

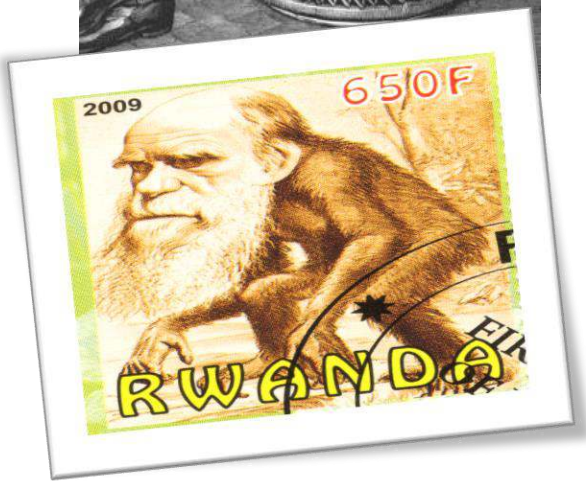
Inheritance part 4 – Theory of evolution (biology only)

In 1831, **Charles Darwin** had the opportunity to join an **expedition around the world** on the H.M.S Beagle.
As a result of years of **experimentation**, **discussion** with other scientists and linked to the developing **knowledge of geology and fossils,** Darwin proposed the **theory of evolution by natural selection**.



His theory was based on **three observations**:

- **Individual** organisms within a particular species show a **wide range of variation** for a characteristic.
- Individuals with characteristics **most suited** to the **environment** are more likely to **breed successfully.**
- The **characteristics** that have enabled these individuals to **survive** are **passed on** to the next generation.



Inheritance part 4 – Theory of evolution (biology only)

Another scientist called **Alfred Russel Wallace,** sent Darwin his ideas and asked for feedback. Darwin had kept his ideas secret for 20 years in fear of losing credibility amongst his peers.
Darwin knew he needed to publish his ideas quickly because **Wallace** was **independently proposing** the **theory of evolution by natural selection**. Wallace published **joint writings** with Darwin in **1858**.

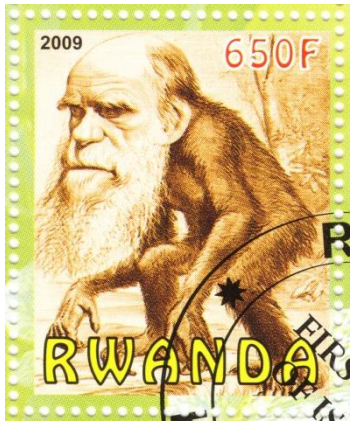
Darwin published '***On the Origin of Species* (1859)**' the following year causing a lot of controversy about these new ideas.
Wallace worked worldwide gathering evidence for evolutionary theory. He is best known for his work on **warning colouration** in animals and his **theory of speciation.** More evidence over time has led us to our current understanding of the theory of speciation.

Speciation = process by which new species are formed

Inheritance part 4 – Theory of evolution (biology)

Darwin's **theory of evolution** by natural selection was only **gradually accepted** because:

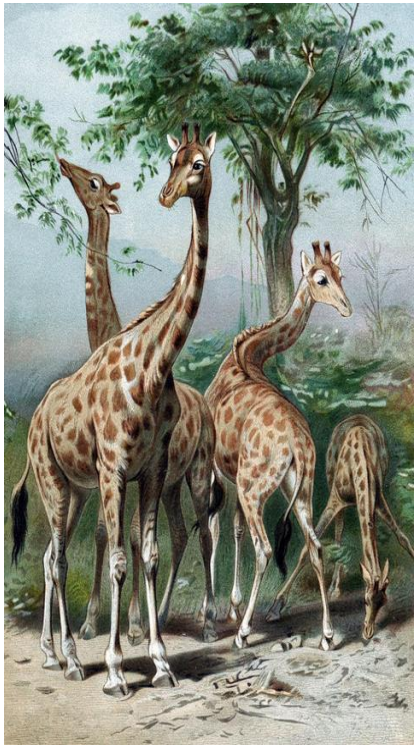
- The theory **challenged** the idea that **God** made all the animals and plants that live on Earth.
- There was **insufficient evidence** at the time the theory was published to convince many scientists.
- The **mechanism of inheritance** and variation was **not known** until 50 years after the theory of evolution was published.



Inheritance part 4 – Theory of evolution (biology only)

Jean-Baptiste Lamarck put forward an early theory of evolution in **1809.**

He proposed that **changes** which occur in an **organism** during its **lifetime** can be **inherited.**



He believed that giraffes had a short necked ancestor.

This ancestor stretched its neck to reach higher leaves on branches and passed on a longer neck to the next generation.

The slightly longer necked giraffe stretched its neck to reach even higher and passed on an even longer neck to its offspring.

In this way the giraffe neck became progressively longer.

We now know that in the vast majority of cases this type of inheritance cannot happen.

Inheritance part 3 – Speciation (biology only)

You need to be able to describe the steps which give rise to new species.

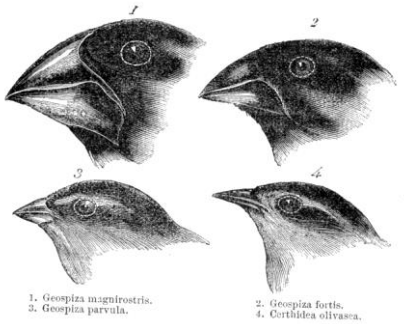
Populations of the same species become isolated from each other.

Environmental conditions differ for each population e.g. available food

Individuals in each population most suited to their environment are more likely to breed successfully

Over time each population will have greater differences in their genotype

Speciation



When two populations of a species become so genetically different that they can no longer interbreed and produce fertile offspring, then two new species have been formed

Speciation allowed biologists to understand the diversity of the species on the planet.

Inheritance part 3 – Speciation (biology only)

A famous example of **speciation** are **Darwin's finches** on the Galapagos islands. Darwin noticed that the finches were **similar** but **showed variation** in size, beak shape and claws **from island to island**.

A **common ancestor** would have arrived on the islands from the mainland and then **different populations** were **established** on each island.

The food source on certain islands was very different. The finches which had beaks **better suited** to the food source had a **survival advantage**. These individuals reproduce and pass on these favourable characteristics to their offspring.

The finches on each island can **no longer interbreed** with those from other islands and produce fertile offspring. **New species** have been **formed**.

Inheritance part 4 – The understanding of genetics (biology only)

Gene theory is the idea that genes are the unit of inheritance. The theory has changed many times as new evidence becomes available. **Many scientists** have contributed to the current understanding. Mendel died long before the idea of gene theory was developed.

Mid 19th Century – Gregor Mendel

One of Mendel's observations on pea plants was that the inheritance of each characteristic is determined by '**units**' that are **passed on** to descendants **unchanged**.

Late 19th Century

The behaviour of **chromosomes** during **cell division** was observed.

Early 20th Century

It was noticed that **chromosomes** and **Mendel's units** behaved similarly. This led to the idea that units now called **genes** were **located on chromosomes.**

Mid 20th century

The **structure of DNA** was determined and the mechanism of **gene function** worked out.

Inheritance part 4 – Evidence for evolution

The **theory of evolution** by natural selection is **now widely accepted.**

Evidence for Darwin's theory is now **available** as it has been shown that characteristics are passed on to offspring in genes.

Darwin, Mendel, Wallace and many more scientists had their credibility questioned in their lifetimes. We can now see their work was **pioneering** and valuable.

Fossils now provide **proof** for **evolution** showing how organisms changed gradually over millions of years.

Our understanding of evolution has also been helped by the **study of antibiotic resistance in bacteria**. Bacteria multiply quickly in a short space of time. Advantageous mutations are rapidly spreading throughout the population of bacteria. We **can see evolution** through natural selection occur and are able to do research.

Inheritance part 4 – Fossils

Fossils are the ‘remains’ of ancient organisms from millions of years ago, which are found in rocks. Scientists can learn how much or how little organisms have changed over time. This is called the fossil record.

Fossils may be formed:

- From parts of organisms that have not yet decayed.
Usually because one or more of the conditions needed for decay is not present (oxygen, water or warmth).

- As preserved traces of organisms such as footprints, burrows and rootlet traces.

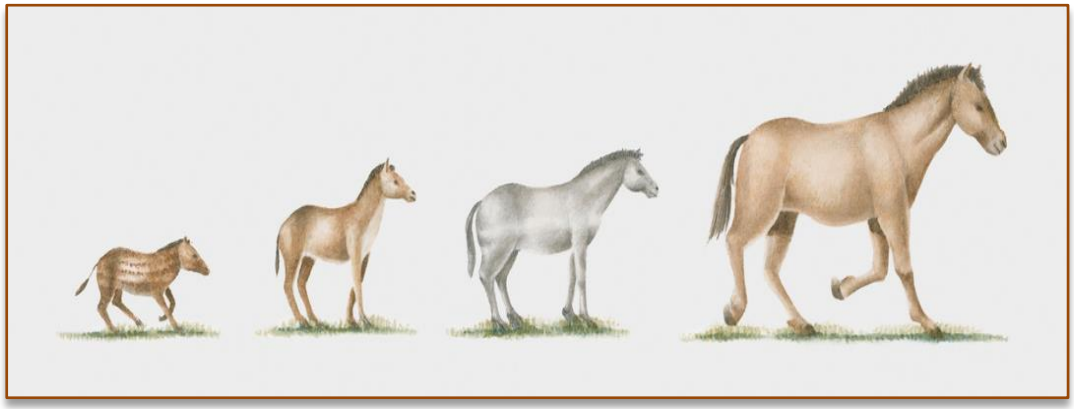
- When parts of the organism are replaced by minerals as they decay.

Inheritance part 4 – Fossils

The **fossil record** is **incomplete** for many reasons:

1. **Early life forms** were often **soft bodied** and so **few traces** remain.
2. Most organisms **do not** become **fossilised** as **conditions** are **rare**.
3. We are **still discovering fossils** which give us more information.
4. **Traces** are often **destroyed** by **geological activity** like earthquakes, volcanic eruptions, formation of mountain ranges and erosion.

This is why scientists can **never be certain** about **how life began** on Earth.



The **fossil record** of the **horse** gives us a good **idea** of how the modern horse has **evolved** from a much smaller, dog like animal.

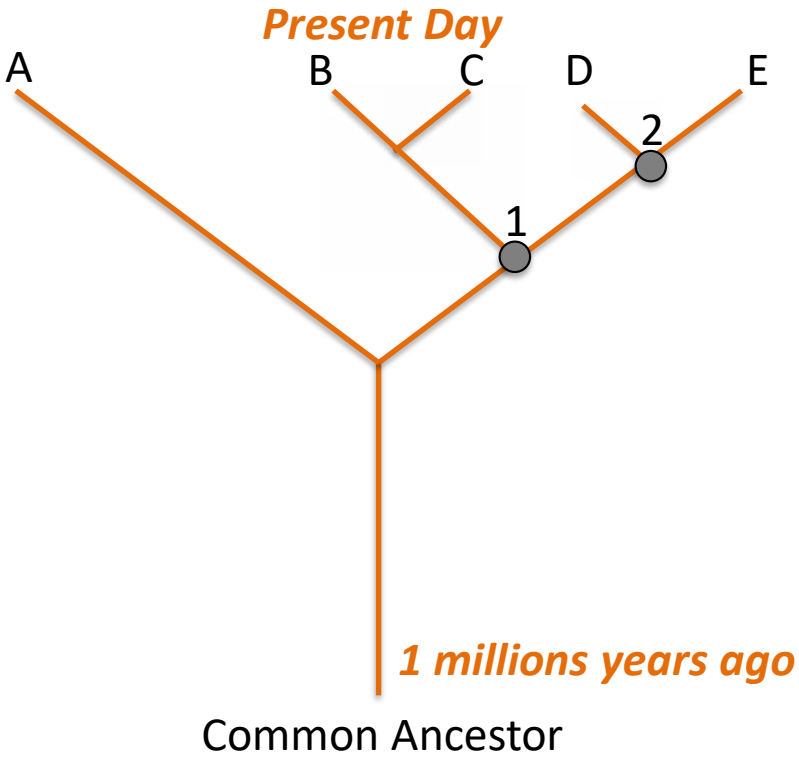
Inheritance part 4 – Fossils

Evolutionary tree diagrams are used to represent the **relationship between** various **species** based on the similarity and differences in their physical and genetic characteristics. The pattern of branching reflects how scientists think the species has evolved from a common ancestor**. Current classification data** is used for living organisms and **fossil data** for **extinct** organisms.

Species A – E all have the same common ancestor.

B and C, D and E share the same ancestor.

A is the present day species least closely related to all other species.



Species A and species 1 evolved from the common ancestor following speciation.

Species 1 was the ancestral species of species B,C and 2.

Species 2 gave rise to species D and E.

Inheritance part 4 – Extinction

Extinction occurs when there are no remaining individuals of a species still alive.

The Dodo is a famous example of an extinct animal. It lived in Mauritius and was a flightless bird. It was first thought the bird was hunted for food to extinction by sailors. That is thought not to be the case now.
It is thought that the animals the sailors brought to the island such as rats, cats and dogs liked the Dodo eggs and so reduced the Dodo numbers by eating the eggs and offspring.

Eventually, around 1660, there were no Dodos left.

No one understood the **concept of extinction** until much later in history and so there are no complete specimens of the Dodo in museums. Most exhibits are made from several individuals birds.

Inheritance part 4 - Extinction

Why do species become extinct?

Climate change: change in rainfall, destruction of habitat, change of temperature

A change in food availability and the inability to find an alternative source

Creation of a new species by speciation that is better adapted to the environment

Failure to reproduce successfully

A new predator or disease that a species cannot defend itself from

Human activity: Road/house building, mining, pollution, poaching, deforestation

Inheritance part 4 – Resistant Bacteria

Bacteria evolve rapidly as they can **reproduce** at a **rapid rate**. **Mutation** of bacterial pathogens produces **new strains**. Some of these strains may be **resistant** to **antibiotics** and are not killed. They **survive** and **reproduce**, so the population of the **resistant strain rises**. The resistant strain will **spread** because people are **not immune** to it and there is **no effective treatment**.

MRSA is a strain of bacteria which is **resistant** to several **antibiotics**.

The development of **new antibiotics** is very **expensive** and **slow**. It can take up to 10 years, once an antibiotic has been found, to bring it to market.

Info graphic: antibiotic resistance

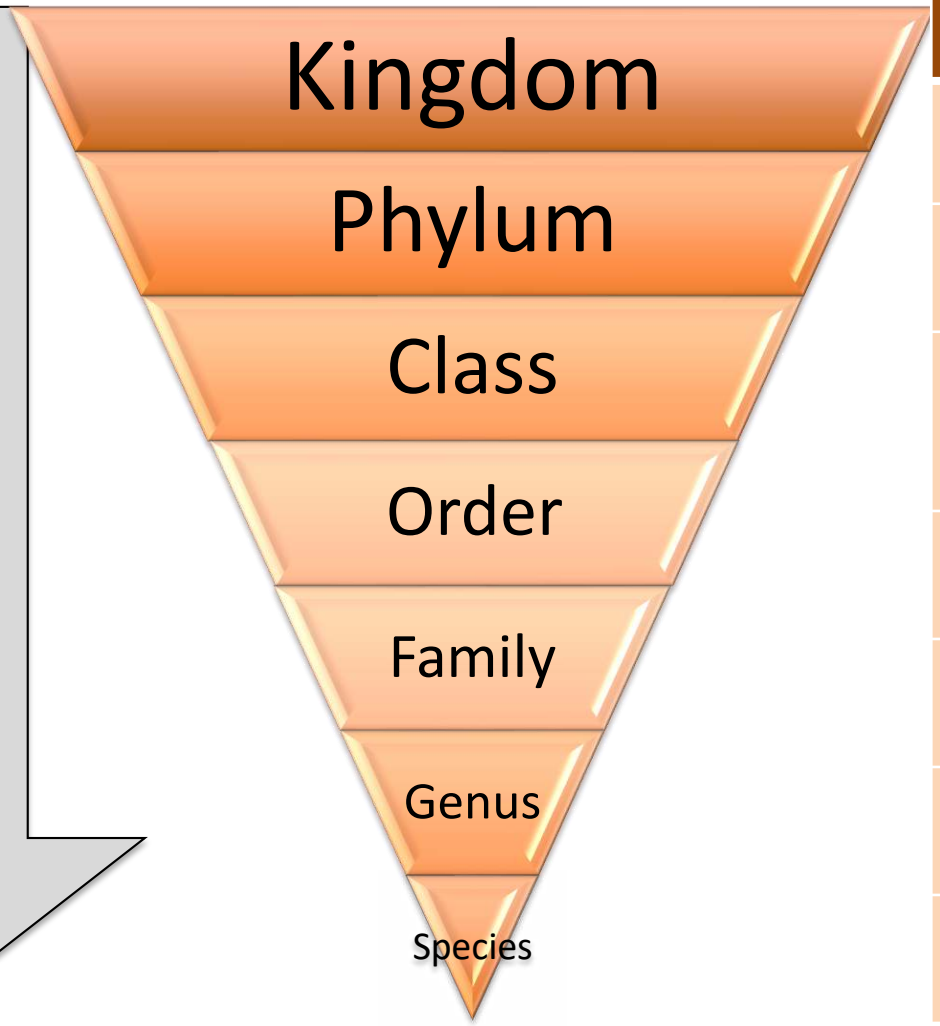
Actions to reduce the rate of development of antibiotic resistant strains are:

- Doctors should **not prescribe antibiotics** for non serious or **viral infections**.
- Patients must **complete the course** of antibiotics to ensure all bacteria are killed and **none survive** to mutate and become resistant.
- **Restrict** the use of antibiotics **in agriculture**. As animals live close together, farmers often use antibiotics in animal feed to **prevent** bacterial infections rather than to **treat** them.

Inheritance part 4 – Classification

Living things have been traditionally classified into groups, depending on the structures and characteristics they share, using a system designed by Swedish scientist Carl Linnaeus.

The number of organisms in each group gets smaller, but they have more features in common.



Group	Human classification
Kingdom	**Animalia**
Phylum	**Chordate** ***With a backbone***
Class	**Mammal** ***Produce milk and live birth, warm blooded***
Order	**Primate** ***Ape like***
Family	**Hominid** ***Human like***
Genus	***Homo*** ***humans***
Species	***Sapiens*** ***Modern humans***

Inheritance part 4 –Classification

Linnaeus recognised there was a problem in terms of naming organisms. Scientists spoke different languages and called the same organisms something different. He developed the **binomial naming system**. Each organism has a **two word name** – the **genus** and the **species**.

These are written in **italics** or underlined. The genus has a capital letter and the species is a lower case letter.

Here are some organisms, their **Latin** name (Genus and species) and common name.

Scientific name	Common name
Felis leo	Lion
Felis domesticus	Domestic cat
Canis lupus	Wolf
Canis familiaris	Domestic dog

Video:

Inheritance part 4 – Classification

As **evidence** of **internal structures** became more developed due to improvements in **microscopes** and the understanding of **biochemical processes** progressed, **new models** of classification were proposed.

In 1977, **Carl Woese** used **evidence** from chemical analysis of RNA to put forward a **three domain system.**

Domain name	Description
archaea	Primitive bacteria usually living in extreme places
bacteria	True bacteria
eukaryota	Includes protists, fungi, plants and animals

QuestionIT!

Inheritance, variation & evolution

Part 4

- Theory of evolution (biology only)
- Speciation (biology only)
- Understanding of genetics (biology only)
- Evidence for evolution
- Fossils
- Extinction
- Resistant bacteria
- Classification of living organisms

Inheritance part 4 – QuestionIT

1. Name **two** pieces of evidence for Darwin's theory of evolution through natural selection which mean it is now largely accepted.
2. What are fossils?
3. How are fossils formed?
4. List two reasons why there are not many traces of early life on Earth.
5. What can be learned from studying fossils?
6. What does an evolutionary tree show?
7. What does it mean when we say an organism is extinct?
8. List **four** factors which may contribute to the extinction of a species.
9. Why do bacteria evolve rapidly?
10. Name a bacterial pathogen which is resistant to several strains of antibiotics.
11. Why are pharmaceutical companies not developing new antibiotics ?
12. Name **three** things that can be done to reduce the rate of development of antibiotic resistance.
13. Name the seven groups that Linnaeus used to classify living organisms.
14. What is the binomial naming system?
15. Carl Woese used information from chemical analysis to suggest a new method of classification. What is it called?
16. List the groups that organisms are divided into using Carl Woese's method.

Inheritance part 4 – QuestionIT(biology only)

1. What theory did Charles Darwin propose?
2. List **three** observations Darwin made which led him to propose his theory.
3. What was Charles Darwin's book called?
4. List **three** reasons why Charles Darwin's theory was only partially accepted.
5. Jean Baptiste Lamarck put forward his theory of evolution. What was his idea?
6. Alfred Wallace also put forward his theory of evolution by natural selection independently to Darwin but what work is he best known for?
7. List the steps needed for a new species to be formed.
8. What did Gregor Mendel observe when he carried out breeding experiments on pea plants?
9. What was discovered in the late 19th century which helped to develop our understanding of genetics further?
10. When was the structure of DNA determined and the mechanism of gene function determined?

AnswerIT!

Inheritance, variation and evolution

Part 4

- Theory of evolution (biology only)
- Speciation (biology only)
- Understanding of genetics (biology only)
- Evidence for evolution
- Fossils
- Extinction
- Resistant bacteria
- Classification of living organisms

Inheritance part 4 – QuestionIT

1. Name two pieces of evidence for Darwin's theory of evolution through natural selection which mean it is now largely accepted.
   Fossil record
   knowledge of how resistance to antibiotics evolves in bacteria
   passing on of characteristics to offspring in genes.
2. What are fossils? ***The remains of organisms from millions of years ago***
3. How many fossils be formed?
   from parts of organisms that have not decayed
   when parts of organism are replaced by minerals
   as preserved traces like footprints, burrows or rootlets.
4. List **two** reasons why there are not many traces of early life on Earth.
   Organisms were mainly soft bodied so little trace left
   Any traces destroyed by geological activity
5. What can be learned from studying fossils?
   how much or how little organisms have changed as life developed on Earth
6. What does an evolutionary tree show?
   how organisms are related using current classification data or fossil data is a species is extinct
7. What does it mean when we say an organism is extinct?
   There are no remaining individuals of a species still alive

8. List **four** factors which may contribute to the extinction of a species.

A change in food availability and the inability to find an alternative source.
Climate change
Creation of a new species by speciation that is better adapted to the environment
Human activity: Road/house building, mining, pollution, poaching, deforestation
A new predator or disease that a species cannot defend itself from.
Failure to breed successfully

9. Why do bacteria evolve rapidly? ***Because they reproduce at a rapid rate***
10. Name a bacterial pathogen which is resistant to several strains of antibiotics. ***MRSA***
11. Why are pharmaceutical companies not developing many new antibiotics ? ***Very costly and takes a long time to develop.***
12. Name **three** things that can be done to reduce the rate of development of antibiotic resistance. ***Doctors should not prescribe antibiotics for non serious or viral infections. Patients must complete the course of antibiotics to ensure all bacteria are killed and none survive to mutate and become resistant. Restrict the use of antibiotics in agriculture***
13. Name the seven groups that Linnaeus used to classify living organisms from largest to smallest. ***Kingdom, phylum, class, order, family, genus, species.***
14. What is the binomial naming system? ***A method of scientifically naming animals using the genus and species.***

15. Carl Woese used information from chemical analysis to suggest a new method of classification. What is it called?
    The three domain system
16. List the groups that organisms are divided into using Carl Woese's method.
    Archaea
    Bacteria
    Eukaryota

Inheritance part 4 – AnswerIT (biology only)

Biology only

1. What theory did Charles Darwin propose?
   The theory of evolution by natural selection.
2. List **three** observations Darwin made which led him to propose his theory.
   - ***Individual organisms within a particular species show a wide range of variation for a characteristic***
   - ***Individuals with characteristics most suited to the environment are more likely to survive to breed successfully***
   - ***The characteristics that have enabled these individuals to survive are then passed on to the next generation***
3. What was Charles Darwin's book called?
   On the Origin of Species
4. List **three** reasons why Charles Darwin's theory was only partially accepted at the time.

i. ***The theory challenged the idea that God made all the animals and plants that lived on Earth***

ii. ***There was insufficient evidence at the time the theory was published to convince many scientists.***

iii. ***The mechanism of inheritance and variation was not known until 50 years after the theory was published.***

Inheritance part 4 – AnswerIT (biology only)

5. Jean Baptiste Lamarck put forward his theory of evolution. What was his idea?
   that changes occur in an organisms life time and these can be inherited.
6. Alfred Wallace also put forward his theory of evolution by natural selection independently to Darwin but what work is he best known for?
   His work on warning colouration in animals and his theory of speciation
7. List the steps needed for a new species to be formed.

- ***Populations of the same species become isolated***
- ***Environmental conditions differ for each population***
- ***Individuals in each population most suited to the environment breed successfully***
- ***Over time each population will have greater differences in their genotype.***
- ***If two populations of one species become so different in phenotype that they can no longer interbreed and produce fertile offspring – 2 new species have been formed.***

8. What did Gregor Mendel observe when he carried out breeding experiments on pea plants? ***Inheritance of each characteristic is determined by units that are passed onto the next generation unchanged.***
9. What was discovered in the late 19th century which helped to develop our understanding of genetics further? ***The behaviour of chromosomes in cell division***
10. When was the structure of DNA determined and the mechanism of gene function determined? **Mid 20th century**