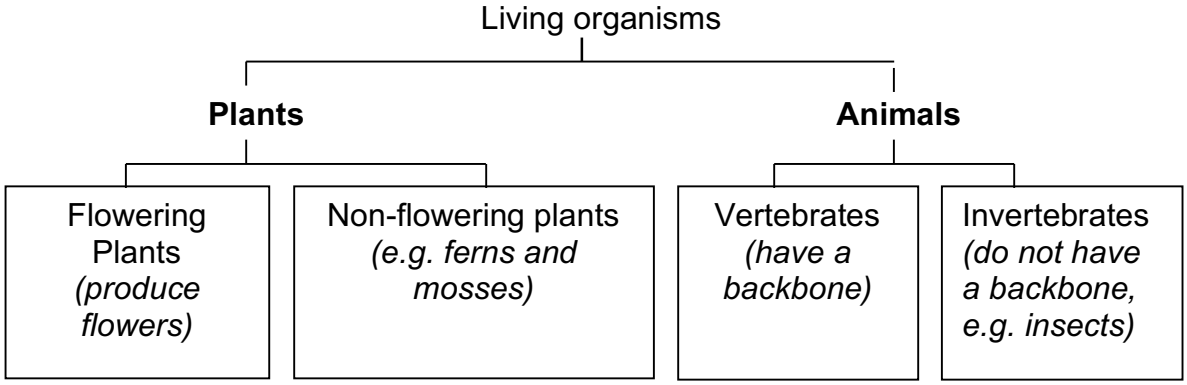
GCSE Science:
Unit 2 Biology / Unit 4 Double Award Revision Book

Contents

Classification – Descriptive Groups

Living organisms show a range of sizes, features and complexity.
They can be divided into broad descriptive groups.



Why and how should organisms be classified?

What does classification mean?
Classification means putting things into groups. A systematic system helps us understand:

- the variety of living things
- how they have changed over time
- how they are related to each other through evolution.

The classification system may be based on:

- morphological features
- DNA analysis

Five Kingdom Classification
The five kingdom classification uses **morphological features**, e.g. **structure** or **appearance**.

This method of classification uses **five kingdoms**:

- Bacteria
- Single Celled organisms
- Plants
- Fungi
- Animals

The names which we use every day for animals and plants, e.g. dog, cat, seagull, daisy, are called **common names**.
Common names are usually based on appearances, which can be misleading,

How are organisms named?
Each organism has a scientific name to aid its identification and classification.

Biologists use the **binomial system** devised by Carl Linnaeus which is in **Latin**.

All organisms are given two names, e.g. *Homo sapiens* for humans or *Erinaeceus europaeus* for the hedgehog.
The first name refers to the **genus** which the organism shares with other closely related organisms.
The second name refers to the **species**; no other organism in the genus has this name.

What is the advantage of using the scientific / Latin name?

- The name is always the same all over the world.
- The name is the same in all languages.
- It avoids the confusion and duplication caused by local or common names.

An example of classification

Scientific classification	Domestic dog	Coyote	Fox
Kingdom	Animalia	Animalia	Animalia
Phylum	Chordata	Chordata	Chordata
Class	Mammalia	Mammalia	Mammalia
Order	Carnivora	Carnivora	Carnivora
Family	Canidae	Canidae	Canidae
Genus	Canis	Canis	Vulpes
Species	lupus	latrans	vulpes

Classification helps us to understand how related organisms are to each other.
The **Latin name** of the domestic dog is *Canis lupus*.
The **genus** shows us that the coyote is more closely related to the domestic dog than the fox.

Adaptations

Organisms have **morphological** (the shape of an organism) and **behavioural** adaptations that enable them to survive in their environment.

Case study – Foxes

The arctic fox is found throughout the artic and sub-arctic tundra whilst the Fennec fox is found in the Sahara and Arabian deserts.

Profiles	Arctic fox	Fennec fox
		
Body mass / kg	6.5 – 17.0	1.0 – 1.5
Ear length / cm	4.0	15.0
Coat colour	White (winter)	Sandy cream

1. **Morphological adaptations**
   - **Ear length**

   Animals with small ears lose less heat because they have a smaller surface area.
   Animals with big ears lose more heat because they have a larger surface area.
   - **Coat Colour**

   A white coat is camouflage against predators or prey in the snow.
   A sandy cream coat is camouflage against predators or prey in the desert.
   - **Body mass**

   Less heat is lost through the surface of an animal with large body mass.
   More heat is lost through the surface of an animal with a small body mass.

2. Behavioural adaptations

The fennec fox is nocturnal (goes out during the night). This is to avoid the heat of the desert during the day. It hunts at night because it is cooler.

Don't always assume that animals are nocturnal to avoid predators or prey.

<u>Pointer</u>

- Questions on adaptation usually contain information about a plant or an animal and their habitat.

Use this information to help you!

Population Size

Population size means how many of **one type of plant or animal** (species) there is in a given ecosystem.

The size of an **animal population** may be affected by:

- Competition for **food** and **water**
- Number of predators
- Disease
- Pollution

Animals will compete for food and water.

The size of a **plant population** may be affected by:

- Competition for **light**, **water** or **minerals**
- Number of herbivores
- Disease
- Pollution

Plants will compete for light, water and minerals.

Organisms that are better adapted to the environment are more successful and usually reproduce more and have more offspring (a new organism).

Definitions to learn:

Interspecific competition - competition between members of different species.

Intraspecific competition - competition between members of the same species.

Biodiversity and Protecting Endangered Species

Biodiversity is the number of different species in a particular area and the numbers of individuals within those species.

Biodiversity is important for:

- food,
- potential foods,
- industrial materials,
- new medicines,
- human well being.

These days more and more species are becoming **extinct** because man is destroying their habitats.
This leads to a **decrease in biodiversity**.
Habitats are being destroyed because of increases in the use of land for:

- Building
- Industry
- Agriculture

The methods of protecting biodiversity and rare species are listed below:

- **CITES** *(Convention on International Trade in Endangered Species) A*greement in the international market to prevent trade in endangered species.
- **SSSI** – Sites of Special Scientific Interest
  Sites that are legally protected because they are rare habitats or contain examples of important or rare species.
- **Captive breeding programs** (e.g. Zoos)
  Protecting rare species by increasing their numbers through breeding programmes before releasing them back into the wild.
- **National Parks**
  Protected areas for the enjoyment of the public due to their natural beauty, plants, animals and geology
- **Seed banks**
  A way of maintaining genetic biodiversity in case a species of plant or animal become extinct.
- **Local biodiversity conservation schemes**
  Plans produced by local authorities with the aim of protecting and enhancing biodiversity.

Studying Ecosystems

How can you find out how many of each species live in an ecosystem?
Sometimes, you can count them, e.g. how many oak trees there are in a small wood. Often it is not that easy.
If you are studying a large area you will have to take a **sample**.

Using quadrats to study plant cover
A quadrat is a square. It can be any size, but one with sides of about 0.5m is convenient to use in a field.

The quadrat can be used to count:

- The number of each species of plant inside it, e.g. number of daisies.
- The percentages cover of a plant, e.g. the percentage area covered by grass.

How can we find out how many organisms there are in an area?

- Select a random sampling method (to avoid any bias).
- A $1m^2$ quadrat is placed randomly and the number of living organism (or percentage cover) in the quadrat is counted.
- This is repeated at least twice **or** until the numbers in the quadrat are consistent.
- An average is calculated of the numbers counted from each quadrat
- The number is multiplied to calculate the total number in the whole lawn.

Example
Scientists sampled a beach with an area of $850m^2$.
They found that the average number of cockles found in a $1m^2$ quadrat was 3.
What was the total number of cockles on the beach?
Answer:
Total number of cockles on beach = 3 cockles/m^2 x $850m^2$ = 2550 cockles

How can we see if the numbers of organisms have changed?

- Use the quadrat method to calculate the number of organisms in an area at the start of the study.
- Use the quadrat method to study the same are after a set period of time (e.g. 1 week, month, every year).
- Note the change to identify a pattern.

How can we find out about the distribution of organisms?

Sometimes investigators want to know:

- **how many** animals and plants are found in an environment,

AND

- **how** the animals and plants are **distributed**.

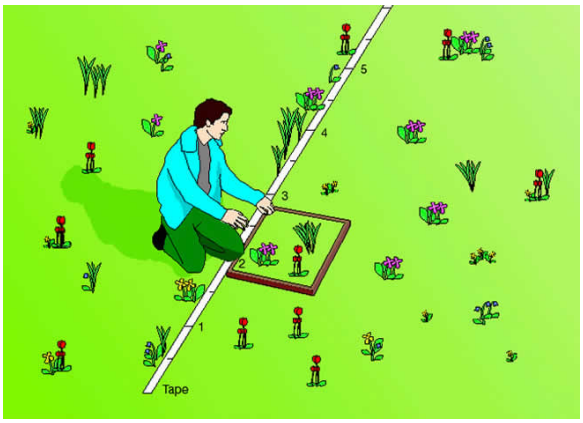
These questions can be answered by using a **transect**.

A transect is a series of quadrat samples taken in a line.

- A tape measure or rope is laid out across the are to be sampled; this is the transect line,
- Quadrats are laid down at regular intervals along the transect line,
- The animals and plants in the quadrats are recorded.

Transects can show:

- **frequency** of a species in a habitat
- **distribution** of species in a habitat



How can we improve the accuracy of sampling?

For the population estimate to be accurate, certain conditions must apply:

- The sample area must be typical of the whole area.
- The bigger the sample area, the better.
  (Very small areas are more likely to be unusual in some way).
- The method of sampling must not affect the results.
  (With some animals, the presence of humans might scare them away, but obviously not snails!).

Samples cannot be absolutely accurate, and scientists often use statistical analysis that takes account of sample size when drawing conclusions.

How can we measure an animal population that moves around?

It is more difficult to measure animal populations in an area than plants, because animals move around.
There is a danger of **counting the same animal more than once**, or of missing **some** which **have just moved out of the sample area**, but will return.
We can solve this problem by using the **capture-recapture technique.**

This technique works by:

- capturing a number of individuals from a species,
- marking them,
- releasing them back into the wild,
- some time later another sample of the species is captured.
- Using a mathematical equation to estimate the population.

This technique makes the following assumptions:

- there is no death
- there is no immigration or emigration
- the marking technique does not affect the chances of survival.

The equation is:

$$N = \frac{MC}{R}$$

- **N** = estimate of total population size.
- **M** = number of animals captured and marked on first visit.
- **C** = number of animals captured on second visit.
- **R** = number of animals captured on second visit that were marked.

Example

50 water beetles were caught and marked (**M**), before being returned to their pond. The next day, 35 water beetles were caught (**C**), 10 of which had been marked (**M**). About how many water beetles were in the pond altogether?

M = 50, **C** = 35, **R** = 10

$$N = \frac{50 \times 35}{10} = 175$$

How can we improve accuracy of the capture-recapture technique?

For the population estimate to be accurate, certain conditions must apply:

- Enough time has passed between the two samples for the marked individuals to mix with the rest of the population.
- There is no large-scale movement of animals in or out of the area in the time between the two samples.
- The marking technique does not affect the survival chances of the animal, e.g. doesn't make it easier to be seen by predators.
- The marking technique doesn't affect the chances of being recaptured, e.g. making it easier to be seen by the collector.

Biological Control of Pests

Chemicals used to control pests (pesticides) can poison the environment. Another way to control them is through using biological control.

Biological control of pests is when another organism (such as a predator or parasite) is used to kill pests.

Example – Control of whitefly in greenhouses

The white fly is a pest on tomato plants in green houses.
A type of wasp lays its eggs inside the white fly larvae.
Using the wasp can reduce the white fly population, as when its eggs hatch they eat the larvae of the white fly.
It only does this to white fly, and has no effect on other insects.
Using an insecticide to kill the flies would kill all insects, even the useful ones like ladybirds and honeybees.
This method is very successful because a greenhouse is a closed environment that can be easily controlled.

Biological control can be purchased mail order!

The whitefly pest

The wasp laying it's eggs in a whitefly egg.

What are the advantages and disadvantages of biological control?

Advantages	Disadvantages
It is specific to a particular pest.	There is a delay between introducing the predator and a reduction in the pest.
Once the predator is established, there is no need to re-introduce it at a later date.	It does not completely eradicate the pest, only brings its number down to acceptable levels.
The pest does not develop resistance to the predator.	

Before considering using a species as a biological control agent thorough **research** needs to be carried out to make sure that this species does not turn out to be a **pest** itself.

Introducing alien species and their effect on native wildlife.

An alien species is an animal or a plant that has been introduced into a country that it does not originate from.

Some animals and plants have been introduced, deliberately and accidentally, into areas where they do not naturally occur.
Some have become invasive and cause problems.

- Invasive species may grow faster than native species and upset the natural ecosystem.
- Native species may not be able to compete.

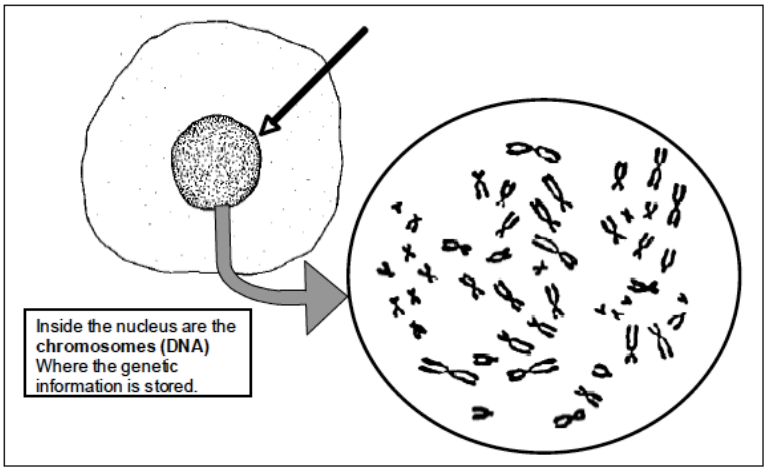
Some problems that alien species can cause are:

- The alien species may have no predators in the area, and its population may grow out of control.
- The alien species may compete with an existing species, causing it to die out in the area. (E.g. animals compete for food; plants compete for light).
- The alien species may prey on existing species, reducing their number.
- The alien species may carry a disease that could affect the native species.

Japanese Knotweed – An Alien Species

Japanese Knotweed *(Fallopia japonicum)* was introduced into Britain as an ornamental plant and is now a pest species in many parts of Britain.
It is a large vigorous weed that has no natural enemies in Britain.
Research is taking place to investigate how an insect (biological control) may be used to control the knotweed.

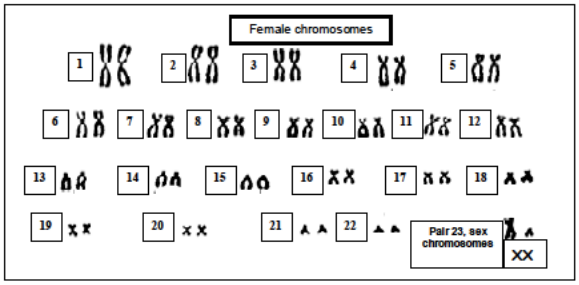
Genetic Information

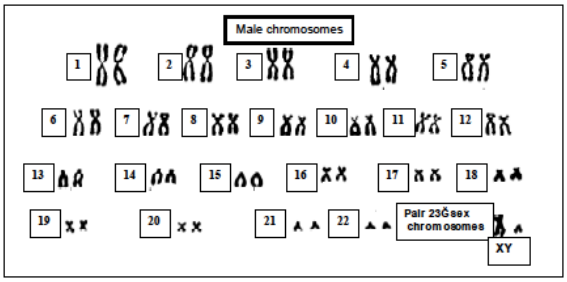


The genetic information to build your body is inside the **nucleus** of each cell.

In humans, there are 23 pairs of chromosomes.

Chromosomes are arranged by **size** and **shape**.



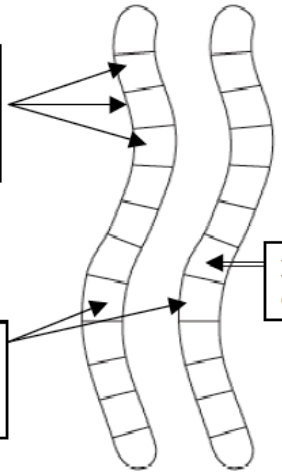


In humans, pair 23 is called the sex chromosomes.

Male = **XY**

Female = **XX**

A single chromosome has lots of information on how to build your body. Each bit of information is called a **gene.**



In body cells, chromosomes are found in pairs.
Genes are therefore found in pairs.

Different genes control different characteristics.

Pairs of genes are found opposite each other at the same position.

Genes are arranged in a row along a chromosome.

Cell Division

1. Mitosis

- This cell division produces **2 genetically identical** cells;
- Each new cell contains **the same number of chromosomes** as the original cell.

Mitosis is needed to:

- Make new cells for **growth** of the body.
- Make new cells to **replace** those that have been **damaged**.
- Make new cells to **replace** those that have **worn out**.

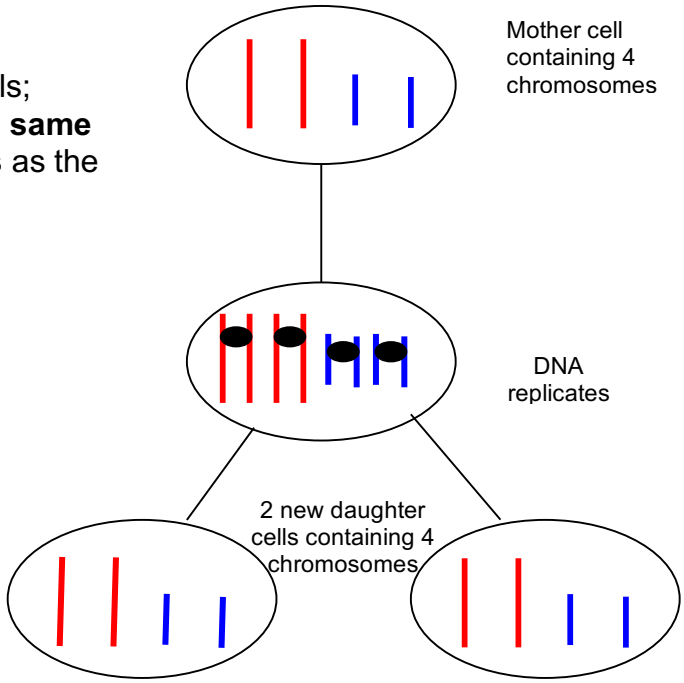
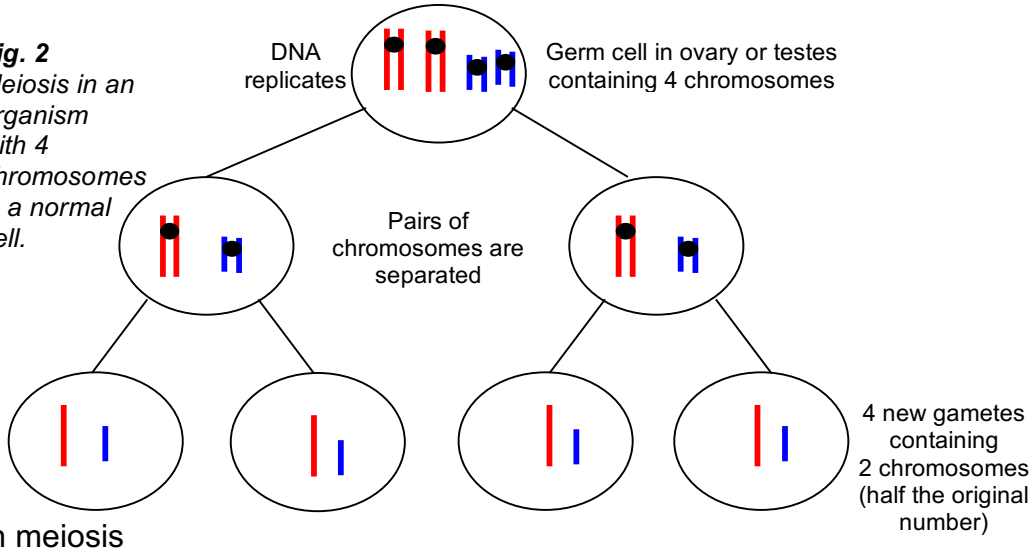


Fig. 1
Mitosis in an organism with 4 chromosomes in a normal cell.
Remember, humans have 46 chromosomes!

2. Meiosis

This cell division produces **4 genetically different** gametes, (sperm or eggs) that contain **half the normal number of chromosomes**.

Fig. 2
Meiosis in an organism with 4 chromosomes in a normal cell.



In meiosis

- Four **gametes** (sex cells) are produced.
- Each **gamete** contains only **one of each pair** of **chromosomes**, so they only contain **half the chromosome number** of the original cell.

Comparing Mitosis and Meiosis

Mitosis	Meiosis
Two daughter cells produced.	4 gametes produced.
New cells contain original number of chromosomes.	New cells contain half the original number of chromosomes.
New cells genetically identical to mother cell.	New cells genetically different to mother cell.

*Be careful, **MITOSIS** and **MEIOSIS** have similar spelling, so examiners expect you to spell them correctly!*

What is the link between mitosis and cancer?

Cell division is controlled by genes. If these genes stop functioning correctly, cells can divide without control.
Cancer is a result of uncontrolled mitosis.

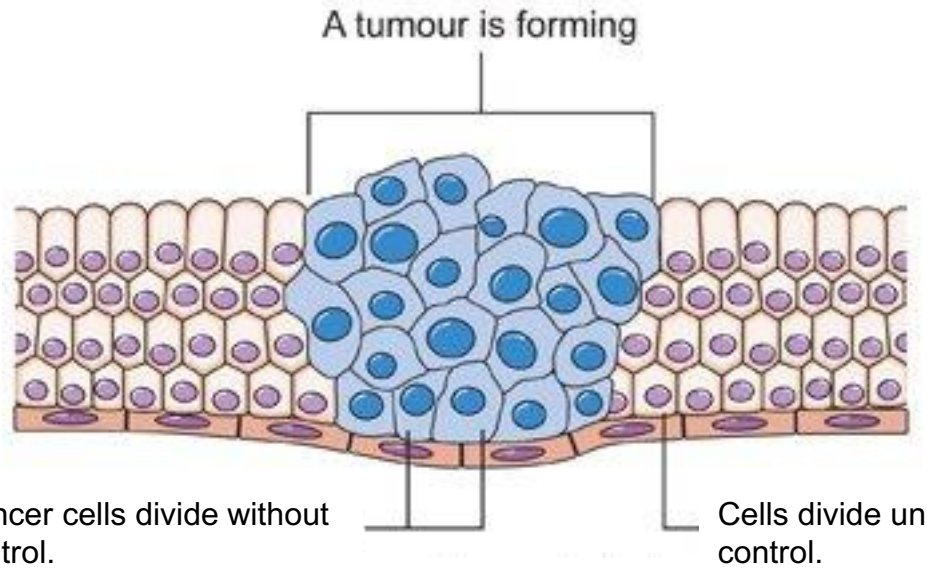


Fig. 1 Illustration of a cancerous tumour developing.
https://www.pathwayz.org/Tree/Plain/FACTORS+THAT+AFFECT+MITOSIS

A cancerous tumour is a group of cells growing out of control. The tumour damages the tissues and organs in which they form.
If some of the cells from the tumour reach the blood they may be carried to other parts of the body where they will continue to grow and form a new tumour.

Stem Cells

Unspecialised cells which have the ability to develop into other cells.

When tissues and organs start to develop, they form specialised cells, e.g. muscle, skin or liver cells.
Once a cell has specialised, it is unable to change into another type of cell, e.g. you cannot use a muscle cell to try and grow skin cells.

Stem cells retain the ability to differentiate into some different types of cells and therefore have the **potential for producing cells by mitosis to replace damaged tissue**.

Source of stem cells in plants:

- **Meristems** – these are growing points in the **tips** of **shoots** and **roots**.

Sources of stem cells in animals:

- Adult stem cells – e.g. from bone marrow, umbilical cord, babies' teeth.
- Embryonic stem cells – from embryo's left over from *in vitro* fertility (IVF) treatment.

What are the uses of stem cell technology?

- Can lead to the **treatment** or a **cure** for many **diseases**.
- Can be used to **replace damaged tissues**, e.g. trachea

The use of stem cell technology raises many issues, which are summarised below:

Type of stem cell	Advantages	Disadvantages
Adult stem cell	• The body will accept the cells so there will be no rejection issues. • No moral or ethical issues involving the destruction of embryos.	• Complicated and the technology is still being developed. • They are unable to differentiate into as many different types of cells.
Embryonic stem cell	• Source of cells readily available from *in vitro* fertility (IVF) treatment.	• Some people believe that destroying embryos means the destruction of potential human life.

How does the nucleus control the cell?

- The nucleus contains chromosomes.
- Chromosomes are strands of DNA.
- Genes are sections of DNA molecules that determine the sequence of amino acids that make up the different types of proteins produced in cells.
- Some of these proteins are enzymes, which control processes.
- These enzymes affect the functioning of the cell and so the organism's inherited characteristics.

What is DNA?

DNA is made up of **two long chains** of **alternating sugar** and **phosphate** molecules **connected by bases**.
This structure is **twisted** to form a **double helix**.

There are four bases:

- Adenine(A)
- Thymine(T)
- Cytosine(C)
- Guanine(G)

There is complementary base pairing between A and T, C and G.

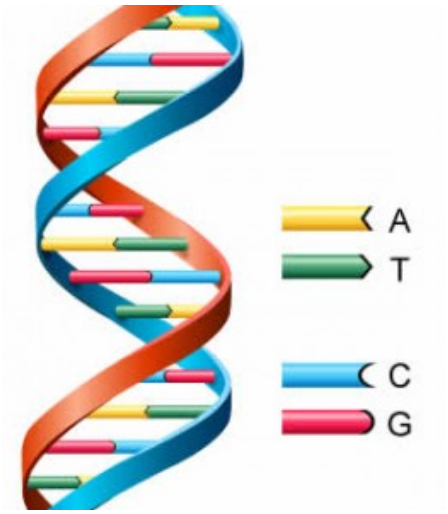


Fig. 1 *– DNA showing two sugar phosphate chains linked by complementary base pairing and twisted into a double helix.*

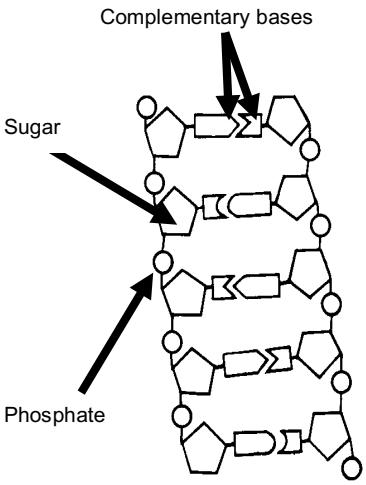


Fig. 2 *Complementary base pairing:*
A and T
C and G

How does DNA Work?

The order of the bases forms a code. Every 3 bases form a triplet code.
This code determines the order in which different amino acids are linked to form different proteins during protein synthesis.

Genetic Profiling

Genetic profiling is the analysis of an organism's DNA.

*(This is commonly referred to as **genetic fingerprinting** – but this term **should not be used** in an exam).*

DNA profiling involves cutting the DNA into short pieces that are then separated into bands.

The pattern of the bands can be compared to show the similarity between two DNA samples.

DNA profiling is used:

- To identify suspects from evidence at crime scenes
- In paternity cases
- In comparisons between species for classification.

It is very unlikely that two organisms have exactly the same genetic profile.

DNA profiling can be used to identify the presence of certain genes that **may** be associated with a particular disease.
The likelihood that these genes may be linked to a particular disease is based on statistical probability.
For example, you may have a gene linked to Type 2 diabetes, but if you live a healthy life style you may never suffer from this problem.

DNA profiling raises several **ethical issues**:

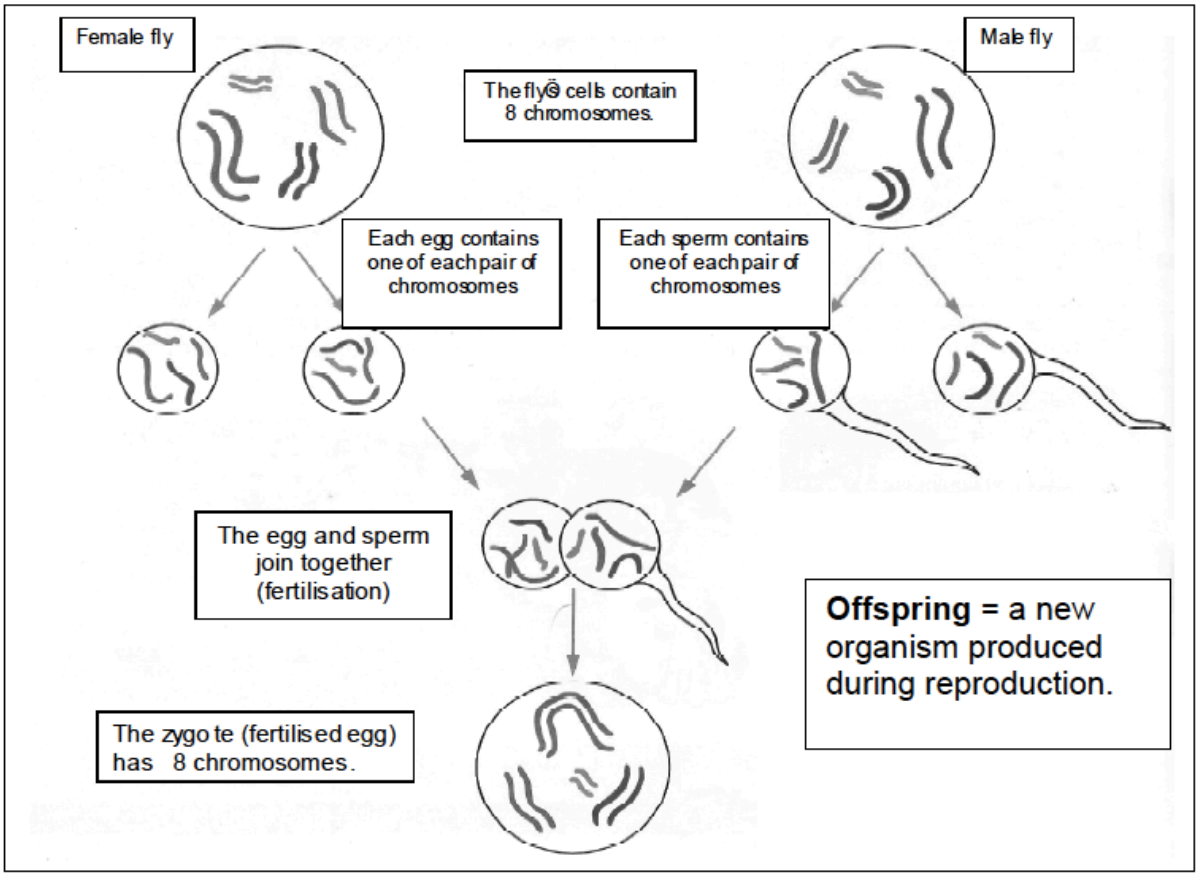
- Who owns the DNA sample involved and who owns the information after analysis?
- Should information on an individual's DNA be kept on record?
- Should third parties, e.g. insurance companies be informed of the presence of a particular gene?

Inheritance and Chromosomes

This is how genetic information is passed from parents to offspring.

- Human body cells contain 46 chromosomes.
- Human sex cells, the sperm and eggs, contain 23 chromosomes. *(The scientific name for a sex cell is **gamete**).*
- Different organisms have different numbers of chromosomes. An onion has 16 chromosomes. A dog has 78 chromosomes.

Example – Inheritance in a fruit fly. (Chromosome number = 8)

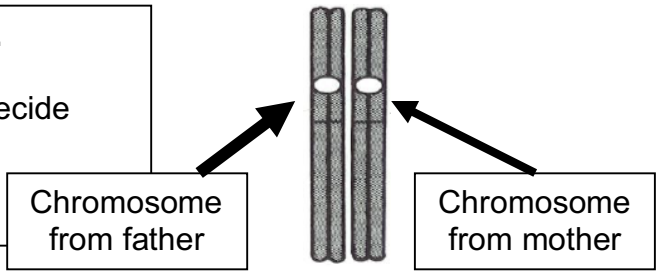


- The number of chromosomes in the egg and sperm are half the number in a normal cell.
- This is so that when they join together in fertilisation the offspring will have the correct number of chromosomes.

Genetics

Genetics is the study of heredity.

It is the **genes** that you have that decide everything about your body!
You have **two** genes for every characteristic.

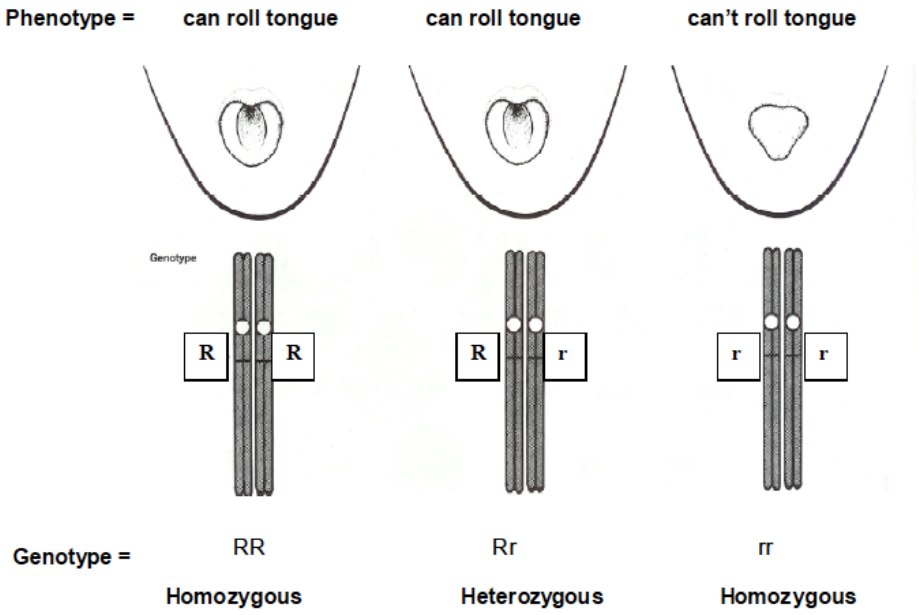


There are lots of **terms** you have to use and learn in genetics.

- **Alleles** - two forms of the same gene, and we use letters to represent them.
- **Genotype** – the genetic make-up, i.e. your alleles.
  *(This is always a **pair** of letters).*
- **Phenotype** – the characteristic that is shown because of your genotype.
- A **dominant** allele will always 'show' in the phenotype when present.
  (This is shown with a CAPITAL letter).
- A **recessive** allele will be 'hidden' when a dominant allele is present in a heterozygote. *(This is represented with a small case letter).*
- **Homozygous** – if the two alleles for a gene are identical.
- **Heterozygous** – if the two alleles for a gene are different.

Example – tongue rolling.

Alleles
R = allele for tongue rolling
r = allele can't roll the tongue.



Genetics Problems

We can use Punnett squares to explain genetic crosses.

Example – Mendel's Peas

Let **T** = tall allele
Let **t** = short allele

1. *Choose a letter to represent the alleles.* ***Capital = dominant****.* ***small case = recessive***

Parent **phenotype** Tall x Short

Parent **genotype** **T T** x t t

2. *The* ***phenotype*** *is the characteristic you see.*

Gametes **T** and **T** **t** and **t**

3. *The* ***genotype*** *is always a* ***pair of alleles (two letters)***

4. *The* ***gamete*** *is always a* ***single allele (one letter)***

F1 cross (First generation)

gametes	**T**	**T**
t	**Tt**	**Tt**
t	**Tt**	**Tt**

All F1 offspring have the **genotype** Tt.
They are heterozygous.
The recessive allele (short) is hidden by the dominant allele (tall.)

An F2 cross can happen when an F1 plant is self-pollinated (selfing)

F2 cross (second generation)

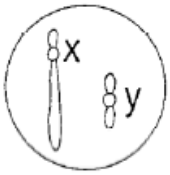
gametes	**T**	**t**
T	**TT**	**Tt**
t	**Tt**	**tt**

Always check to see if you are asked to describe the ***probability*** *or the* ***ratio*** *of results.*

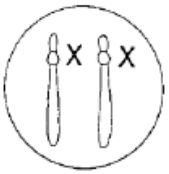
The **ratio** of tall to short plants = 3 tall : 1 short

The **probability** of a tall plant = 75%
The **probability** of a short plant = 25%

Inheritance of Sex



Father's cells contain one X and one Y chromosome.



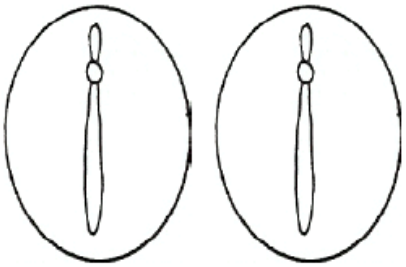
Mother's cells contain two X chromosomes.

Cells In the testes divide to produce sperm.
One of the sex chromosomes goes into each sperm.

Cells In the ovaries divide to produce eggs .
One of the sex chromosomes goes into each egg.

Y Sperm

X Sperm



Each egg contains an X chromosome

Equal numbers of X sperms and Y sperms are produced.
The **probability** of the baby being a boy or a girl is 50%.

Man

Woman	gametes	X	Y
	X	XX	XY
	X	XX	XY

We can show this using a Punnett square.

The Punnett square shows all the possible combinations from mixing the sperm and eggs.

Genetically Modified (GM) Crops

Transferring genes artificially from one **species** to another.

Case Study – Herbicide resistance in Soya beans.

Herbicides are chemicals that farmers use to kill plants that compete with crops.

Herbicide resistant Soya plants have been produced using the following method:

1. Genes from resistant plants are “cut out” using enzymes.
2. They are then transferred into the chromosomes of Soya bean plant cells.
3. The modified cells are cloned to produce GM plants resistant to herbicide.

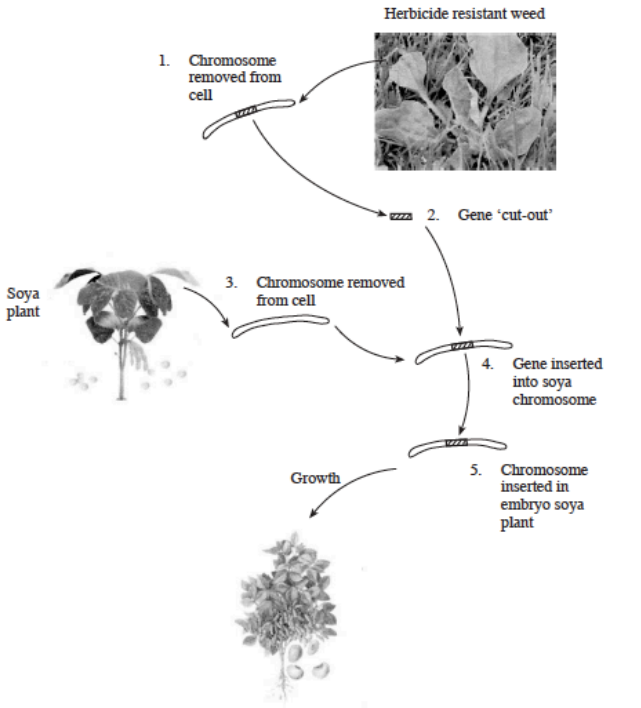
Advantages

- Plants that are resistant to herbicides can be sprayed with that herbicide to kill weeds leaving the plant unaffected.
- This leads to increased yields due to reduced competition for space and nutrients.

Disadvantages

Concerns about:

- The health effect of eating them,
- The escape of transferred genes into other plant species,
- The creation of super weeds resistant to herbicides,
- Unknown long-term effects.



GM soya resistant to weed killer

Why is it important to carry out extensive field trials of GM technology?

- To understand the possible effects on the environment.
- To identify any possible health problems.
- To check for possible transfer of genes to other species.

Variation

Variation means the differences between individuals of the same species.

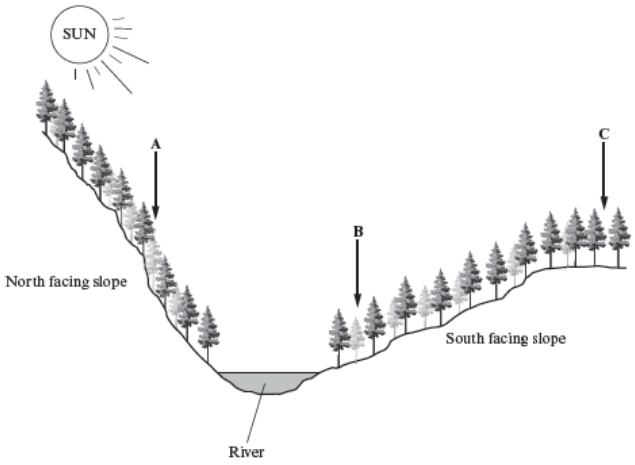
Heritable variation is the basis of evolution.

Variations are the result of
- **Genetic information** (genes)
- The **environment**

Some variations are the result of genes only, but most variations are caused by a combination of genes and the environment.

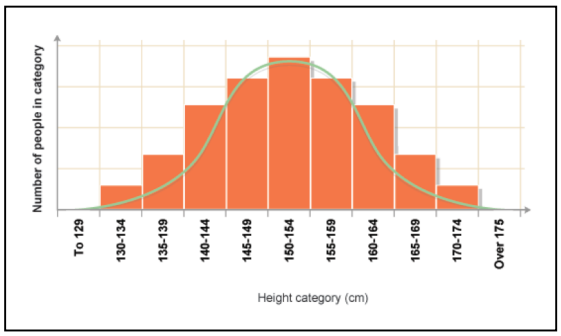
Plant growth is more affected by the environment.

Some of these environmental factors are:
- Availability or competition for water,
- Competition for light,
- Air or soil temperature,
- Aspect of slope, e.g. a south facing slope gets more sunlight.

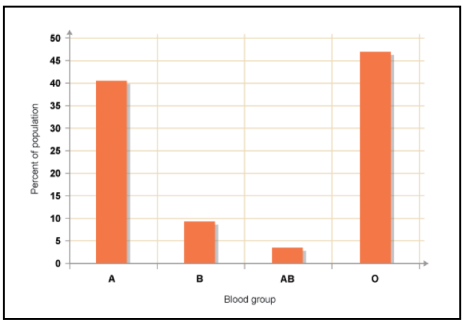


Types of variation:
- **Continuous variation** is controlled by more than one set of genes. When described using a graph it shows a normal distribution, e.g. height.
- **Discontinuous variation** is usually controlled by one set of genes. When graphed it shows distinct groups, e.g. blood groups.

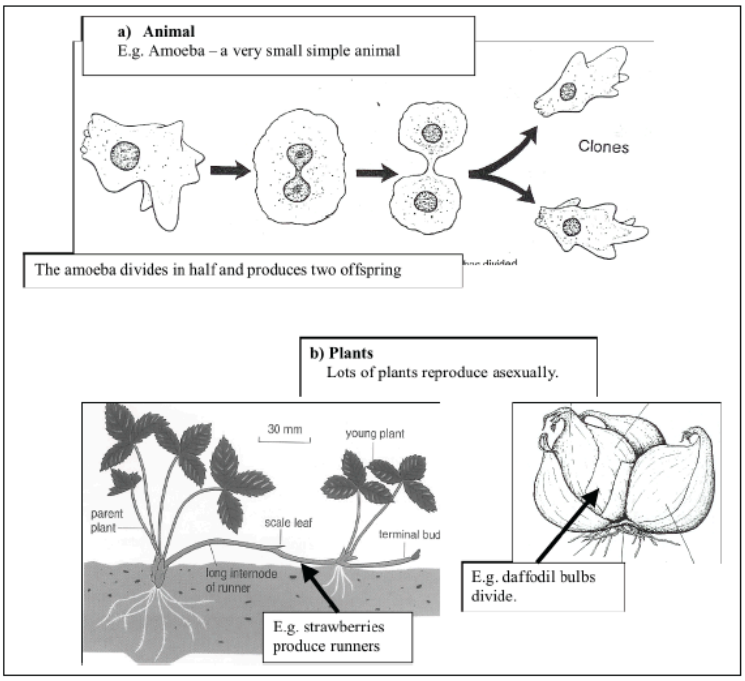
Continuous variation



Discontinuous variation



Reproduction - production of new organisms (offspring)



Asexual Reproduction

In this type of reproduction

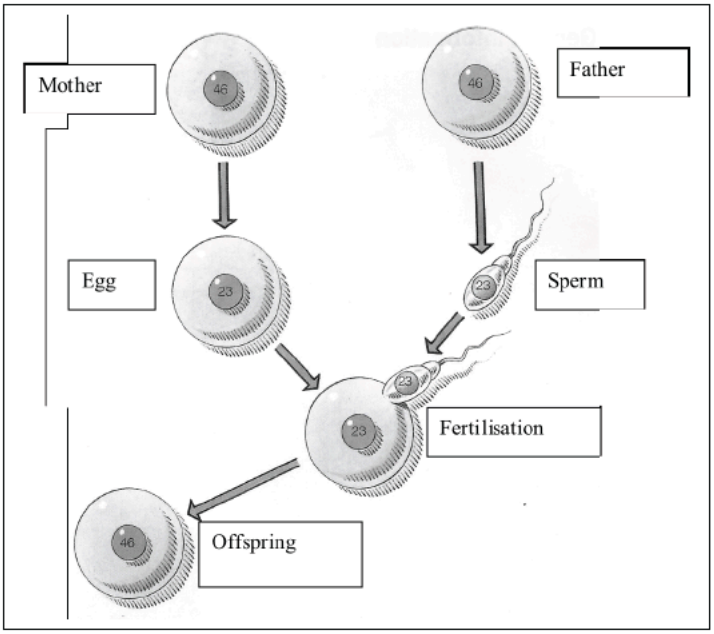
- There is only **one parent.**
- The offspring are **genetically identical** to the parent.
- There is **no variation** between the offspring.

Genetically identical organisms are called **clones**.

Sexual reproduction

In this type of reproduction

- There are **two parents.**
- Fertilisation produces a single cell with a new set of pairs of chromosomes.
- The offspring are **genetically different** because they have genetic information (chromosomes / DNA) from both parents.
- There is **variation** between the offspring.



Comparison of sexual and asexual reproduction:

Asexual reproduction	Sexual reproduction
No variation between offspring	Variation between offspring
Offspring genetically identical (clones)	Offspring genetically different
Offspring develop from one parent	Offspring develop from two parents

Mutations

A mutation is a change in the DNA molecule resulting in a new gene. This can result in a new characteristic that **may** be passed onto the next generation.

Mutations happen naturally at random or in response to natural background radiation. The **probability** of a mutation happening is **increased** if you are exposed to:

- Ionising radiation
- X-rays
- Ultra violet radiation from the sun
- Some toxic chemicals (mutagens)

The greater the dose, the greater the chance of a mutation in genes.

Most mutations are not noticed, either because the mutant cell is just one amongst millions of ordinary cells, or because it is destroyed by the white blood cells. **Mutations are only passed on if they are in a gamete** (sex cell).

Harmful mutations

- In reproductive cells, mutations can cause **abnormalities** or **death** in the young.
- Mutations in body cells can cause them to divide uncontrollably – **cancer**.

Neutral mutations

- These do not affect the survival rate of an organism, e.g. appearance of blue budgies.

Beneficial mutations

- These mutations give an organism an advantage that allows it to survive and breed, e.g. bacteria that are resistant to antibiotics are able to survive and create an antibiotic resistant strain of bacteria.
  (This is an example of natural selection and evolution).

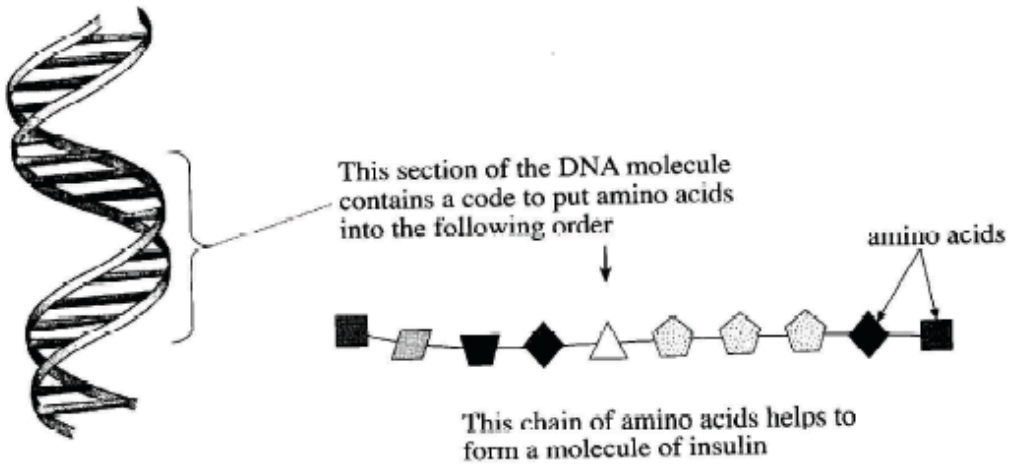
Genes and Health

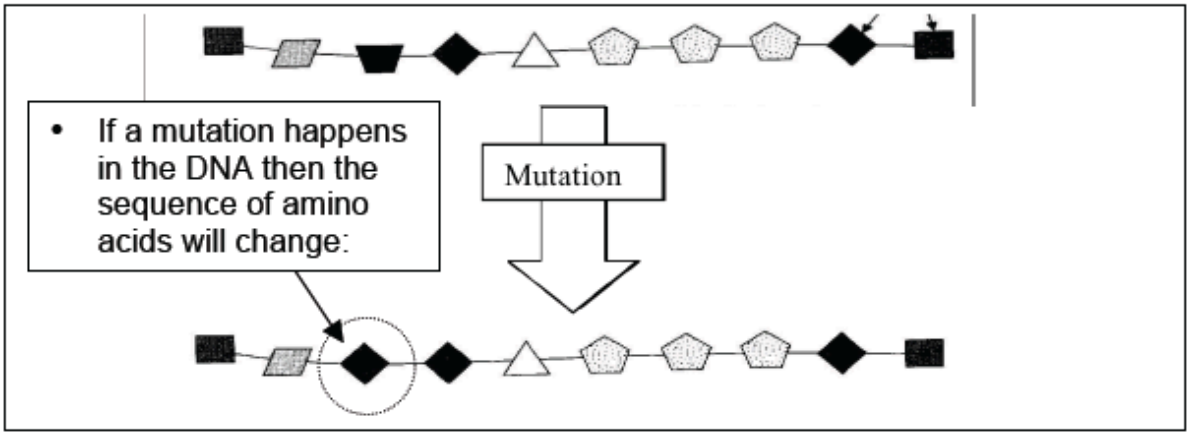
Some diseases are caused by changes in genes (mutations). These diseases can be inherited. Modern medical research has led to the development of **genetic screening** and **gene therapy**.

Tests are available to find out if you are a carrier for some disorders such as **cystic fibrosis**.
Prenatal genetic tests are also available to test foetuses during pregnancy. Small samples of cells from the membranes surrounding the foetuses are taken. The DNA from these cells is analysed.

DNA and Mutations

- Chromosomes are strands of DNA and genes are sections of DNA molecules.
- DNA contains coded information which determines the sequence of amino acids which make up the different types of proteins produced in the cell.
- Some proteins are enzymes which control processes within the cell. These enzymes in turn affect the functioning of the cell and so the organism's inherited characteristics.





- The protein will then be different which will affect the functioning or characteristics of the organism.

Inherited Diseases – Cystic Fibrosis

Genetic information can contain a 'fault' or a damaged code in the DNA.
If this fault is inherited it can cause a disease that can't be cured because the faulty information is inside every cell.

Cystic Fibrosis is an inherited disease.
A person with cystic fibrosis produces very thick mucus in their lungs.
The mucus slows down exchange of gasses in the lungs; it's also a breeding ground for bacteria.
At least once a day a person with cystic fibrosis must have physiotherapy to move this thick mucus out of the lungs.

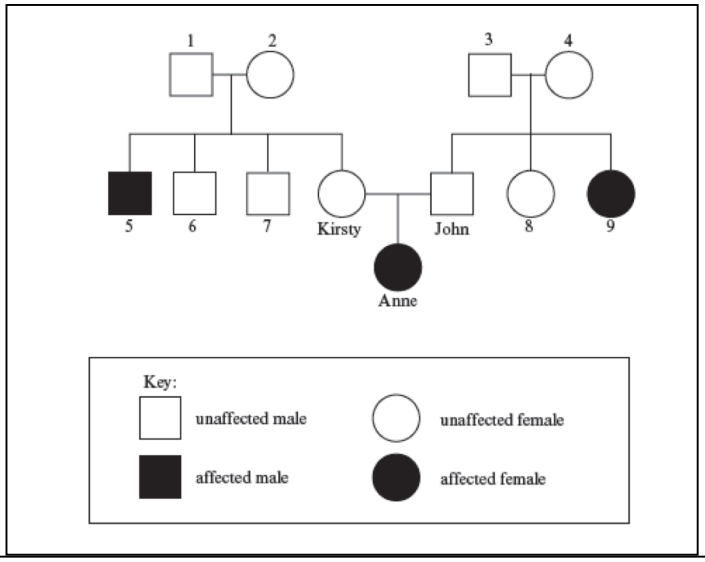
Genetic explanation.
In humans, there are two kinds of alleles that code for mucus.

- One allele codes for normal mucus (N)
- The other codes for thick mucus (n)

There are three possible combinations of these alleles:

NN **Normal mucus**	**Nn** **Normal mucus**	**nn** **Thick mucus**

The inheritance of genetic diseases can be shown using family trees.



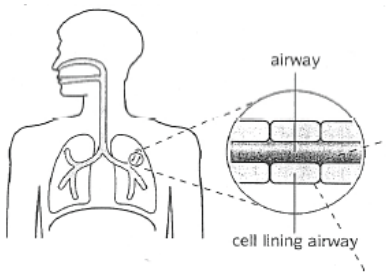
- The **genotype** causing cystic fibrosis is **nn**, e.g. Anne, male 5 and female 9.
- An individual with genotype **Nn** produces normal mucus. They do not have Cystic Fibrosis because they carry one copy of the dominant gene.
- Individuals with the genotype **Nn** are called **carriers** because they are not affected by the disease but may pass it on to any of their children, e.g. Kirsty, John, individuals 1, 2, 3 and 4.

Gene therapy

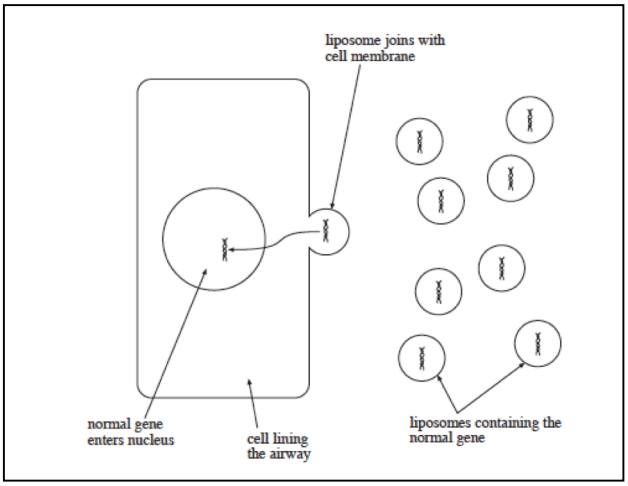
Gene therapy may offer a solution to the problem of genetic disorders.

Doctors are trying to use gene therapy to treat cystic fibrosis.

- Genes for normal mucus are **inhaled** into the lungs using an inhaler, like an asthma inhaler.



- Some cells that make mucus take in the gene and produce normal mucus for a few days.



- However, new cells produced by the body will not contain the gene for normal mucus.
- The inhaler will need to be used every few days so that the person has a healthier life.

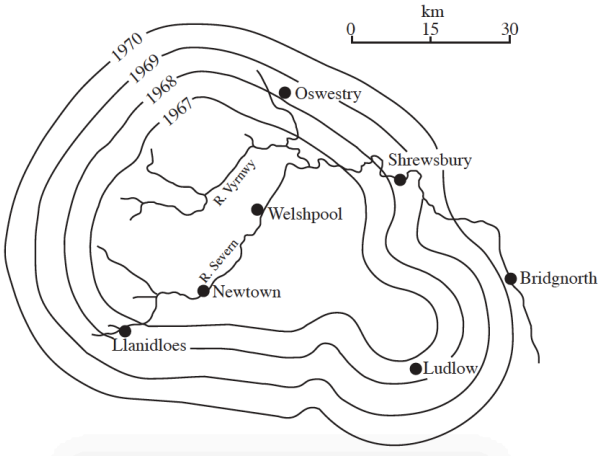
Evolution

Evolution is the **gradual change** in species **over time**, resulting in the formation of new species, and the extinction of others.
Evolution is a process which is ongoing.

Alfred Russell Wallace and **Charles** Darwin were both working on the ideas of evolution and natural selection at around the same time but independently of each other.
It is now accepted that the mechanism for evolution is **natural selection**.

Warfarin Resistance in Rats - An Example of Natural Selection

In 1959, Warfarin-resistant rats appeared in Welshpool in mid-Wales and began to spread. The spread of Warfarin resistance between 1967 and 1970 is shown in the map below.



1. There is **variation** in a population. (New variation appears because of mutations that can be inherited).
2. Some individuals have a **characteristic** that gives them an **advantage**. (E.g. some rats are resistant to the poison Warfarin, whilst others are not resistant).
3. There is **competition** for survival.
4. The individuals that survive are more likely to **reproduce** and **pass the gene** (that controls the characteristic giving them the advantage - the Warfarin resistant gene) **on to their offspring**.
5. Over a long period of time the advantageous gene will become more common in the population, (provided the environment does not change, i.e. people stop using Warfarin).

Species that have a lot of variation carry many versions of the same genes. They are more likely to be able to survive if the environment changes suddenly.
Species that don't have much variation are less likely to adapt quickly when the environment changes and will become **extinct**.
However, the process of natural selection is sometimes too slow for organisms to adapt to new environmental conditions and so organisms may become extinct.

The Nervous System

Central nervous system:
- Brain
- Spinal cord

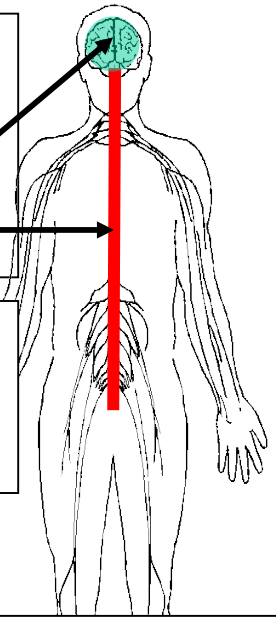


Fig. 1 Illustration of central nervous system

Humans have 5 sense organs connected to the nervous system.

Each sense organ is made up of special cells called **receptors**.
The receptors can respond to a certain **stimulus**.

The receptors collect information from out surroundings and **pass the information as electrical impulses along neurones to the central nervous system**.

The central nervous system (the **brain** or **spinal cord**) can then store the information or decide on a reaction.

The table below lists the sense organs and the stimulus or stimuli that it detects:

Sense organ	Stimulus
Eye	Light
Ear	Sound
Nose	Chemicals (in the air)
Tongue	Chemicals (in food)
Skin	Touch / Temperature / Pressure

Reflex Actions

Reflex actions are:
- protective,
- automatic,
- fast.

Fig. 2 – Illustration of a knee jerk reflex. When the hammer strikes the tendon below the knee cap tension increases in the leg muscle, causing it to contract. This reflex helps keep us upright.

Examples of reflex actions:

Reflex	Explanation
Blinking	Protection of the eye
Change in pupil diameter	Protection of the retina
Withdrawal / pulling away	Prevent harm to the body
Sneezing	Expel substances form the nose
Knee jerk	Helps maintain posture

The Reflex Arc

All reflex actions follow the same order:

1. Stimulus
2. Receptor
3. Sensory neurone
4. Co-ordinator
5. Motor neurone
6. Effector
7. Response

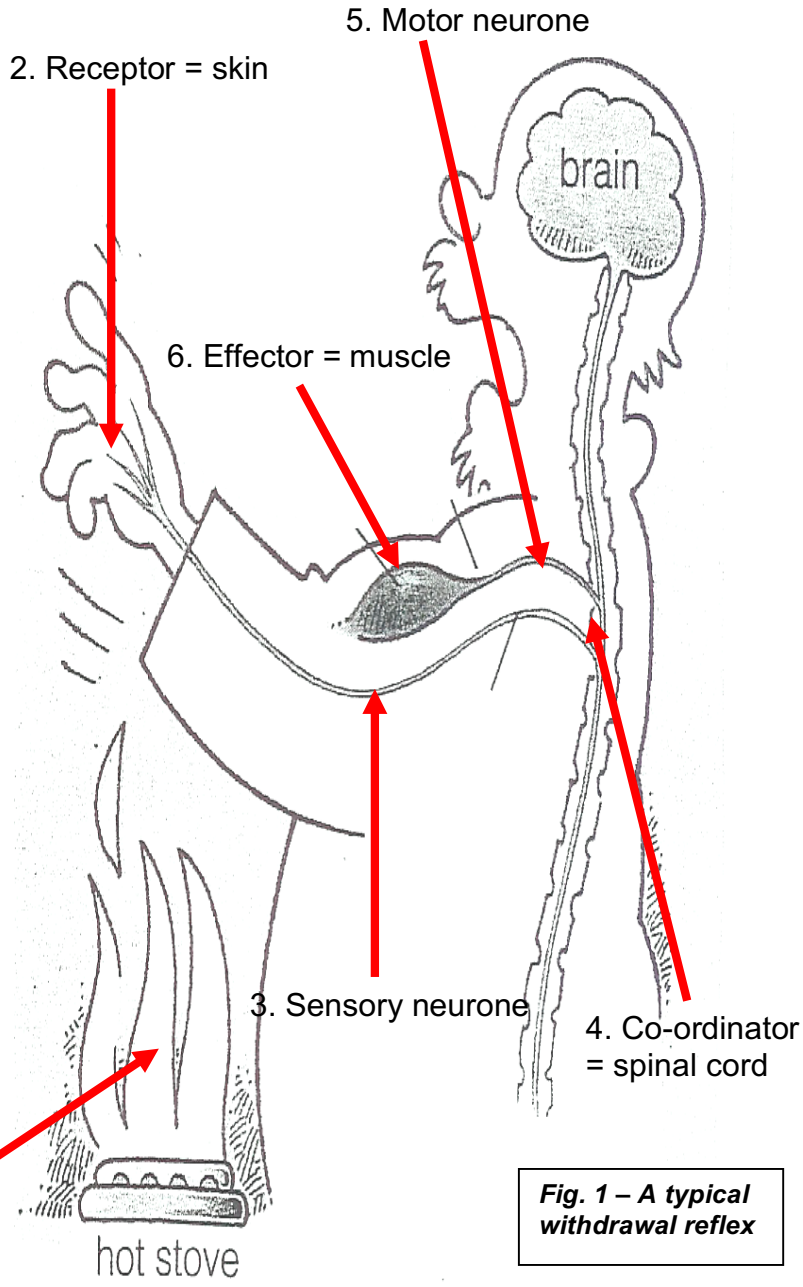


Fig. 1 – A typical withdrawal reflex

The **co-ordinator** is always either the **brain** or the **spinal cord**.

The **effector** is always a **muscle** or a **gland.**

The Structure of a Reflex Arc

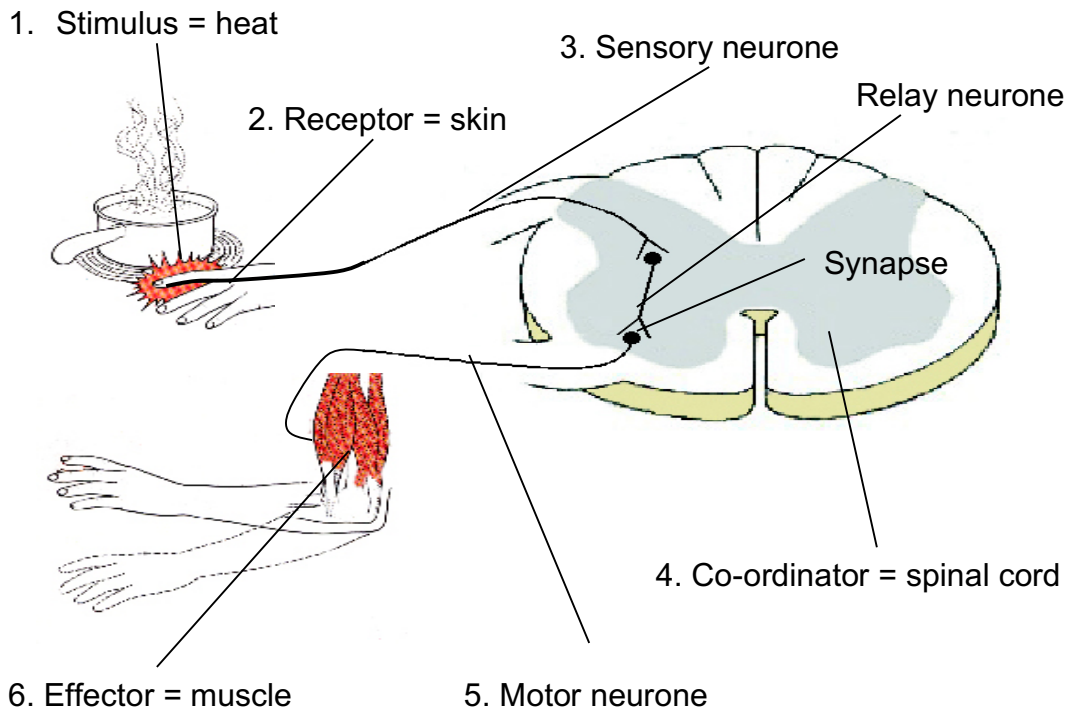


Fig. 1 – The structure of a reflex arc showing relative positions of each neurone.

Describing the path taken by a nerve impulse from the receptor to the effector.

- The **stimulus** (heat) is detected by **receptors** in the skin.
- The receptor responds and sends and **electrical impulse** along a **sensory neurone** to the **co-ordinator** (the spinal cord).
- The electrical impulse is passed to a **relay neurone** inside the spinal cord and then on to the **motor neurone**.
- Between each neurone is a tiny gap called a **synapse**.
- The **motor neurone** carries the impulse to the **effector** (the muscle).
- The muscle contracts and pulls the hand away from the stimulus; this is the **response**.

The Eye

The eye is a sense organ that contains light receptors.

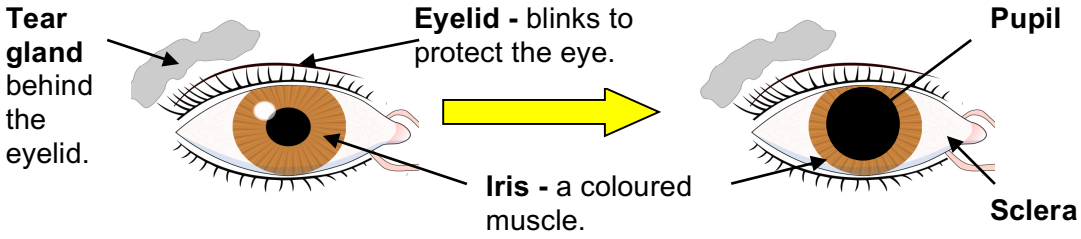
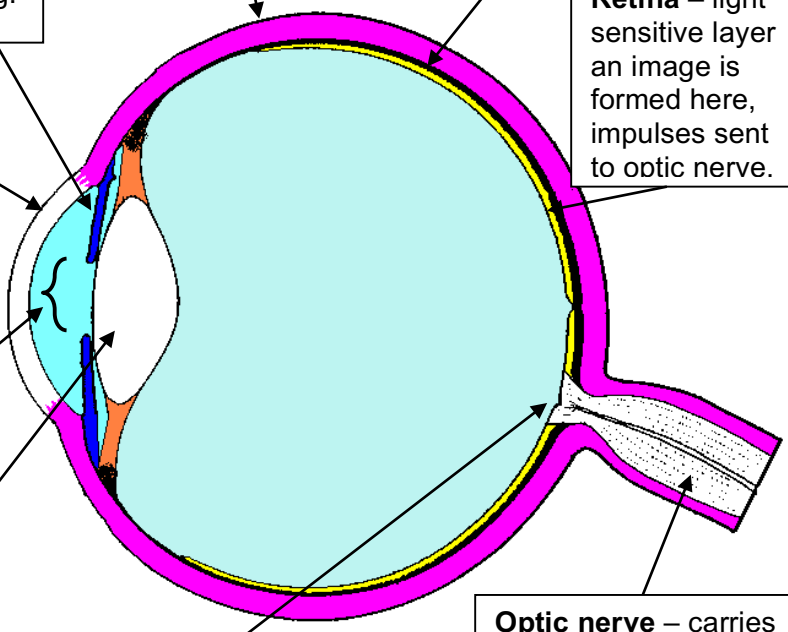


Fig. 1 – Front view of an eye in bright light (left) and in dim light (right). The iris controls how much light enters the eye by changing the size of the pupil. This reflex action protects the retina.

Internal Structure of the Eye



Sclera – protective, tough white outer coat.

Choroid – a pigmented layer which absorbs light to prevent reflection, also contains blood vessels

Iris – muscles that alter size of pupil to control amount of light entering.

Retina – light sensitive layer an image is formed here, impulses sent to optic nerve.

Cornea – clear part of sclera allows light to enter and refracts light entering.

Pupil – hole in centre of the iris which allows light to enter.

Lens – changes shape to focus light onto retina.

Blind spot – where the optic nerve leaves the eye, there are no light sensitive cells here.

Optic nerve – carries impulses from retina to brain.

Fig. 2 – vertical section through the eye.

Homeostasis

Body cells work efficiently when they are at the appropriate **temperature**, **pH** and are supplied with the correct **concentration of nutrients** and **water**.

Homeostasis means keeping the internal environment constant

Conditions inside the body must be kept stable.

Examples to learn:

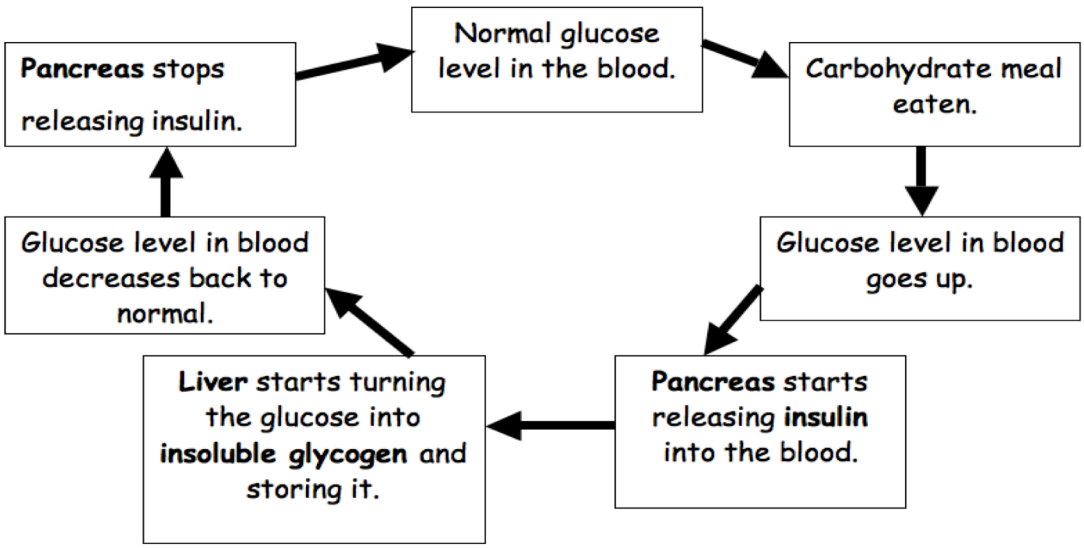
- **Water content** of the body must be kept constant
- **Waste chemicals** must be removed from the body
- **Body temperature** must remain constant
- **Glucose levels** must remain constant

Hormones are chemical messengers that control many body functions.
They are produced by glands and carried by the blood.
Hormones are proteins.

Insulin is a hormone that controls blood glucose levels.

Controlling Blood Glucose Levels – An Example of Negative Feedback

Eating **carbohydrate** foods, e.g. bread and rice puts a lot of **glucose** into the blood when they are digested.



Diabetes

Diabetes is a condition where the level of glucose in the blood can't be controlled.

The diabetic can't store glucose and the level in the blood can rise to a level that is very dangerous.
The normal level of glucose in the blood is 0.1g per $100cm^3$. Above this level, the glucose is excreted in the urine by the kidneys.

Symptoms of diabetes

1. **Glucose** excreted **in the urine**.
2. **Lots of urine** produced as the glucose is diluted with lots of water.
3. Feeling **thirsty**, because a lot of water has been lost in the urine.
4. **Loss of weight** and **feeling weak** because glucose isn't stored and used by the body.
5. Diabetic **coma** in extreme cases.

Diagnosis of diabetes

1. Test urine for glucose.
2. Test blood for higher than normal glucose levels.

Treatment of diabetes

1. Regular injections of insulin into the body.
2. Controlling the carbohydrate and fat content of a diet.
3. Possible transplant of pancreatic tissue.

Diabetes (**type 1**) is a condition in which a person's blood glucose may rise to a fatally high level because the body does not produce insulin.

Diabetes (**type 2**) develops when the body can still make some insulin, but not enough, or when the insulin that is produced does not work properly (known as insulin resistance).
In most cases this is linked with being overweight (because of too much carbohydrate and fat in the diet and a lack of exercise).
This type of diabetes usually appears in people over the age of 40, though in South Asian and African-Caribbean people, it often appears after the age of 25.
Type 2 diabetes accounts for around 90 per cent of people with diabetes.

The Principles of Negative Feedback

Any change from the balance in optimal internal conditions results in the body's hormonal and nervous system compensating for the change and restoring the balance.

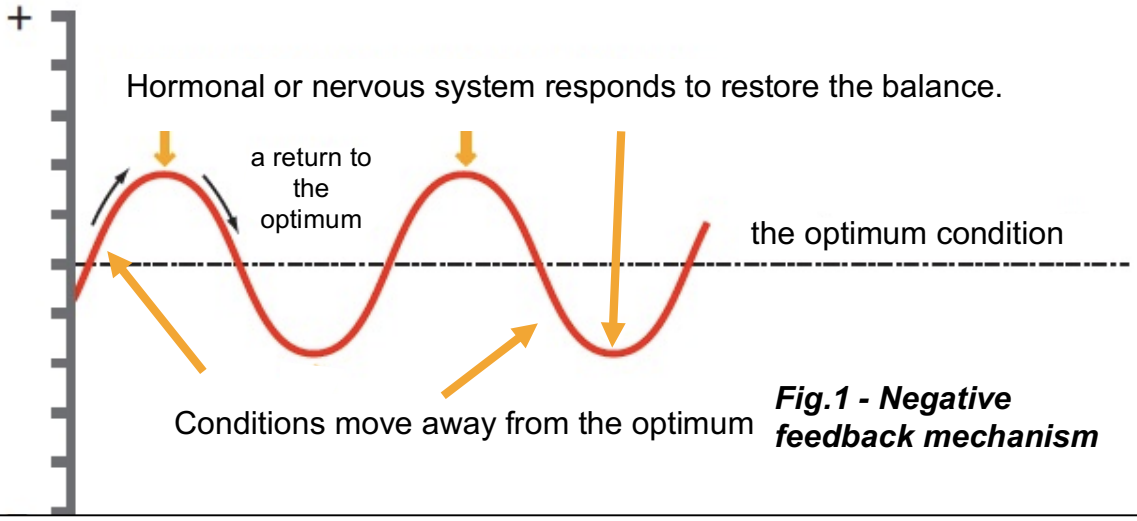
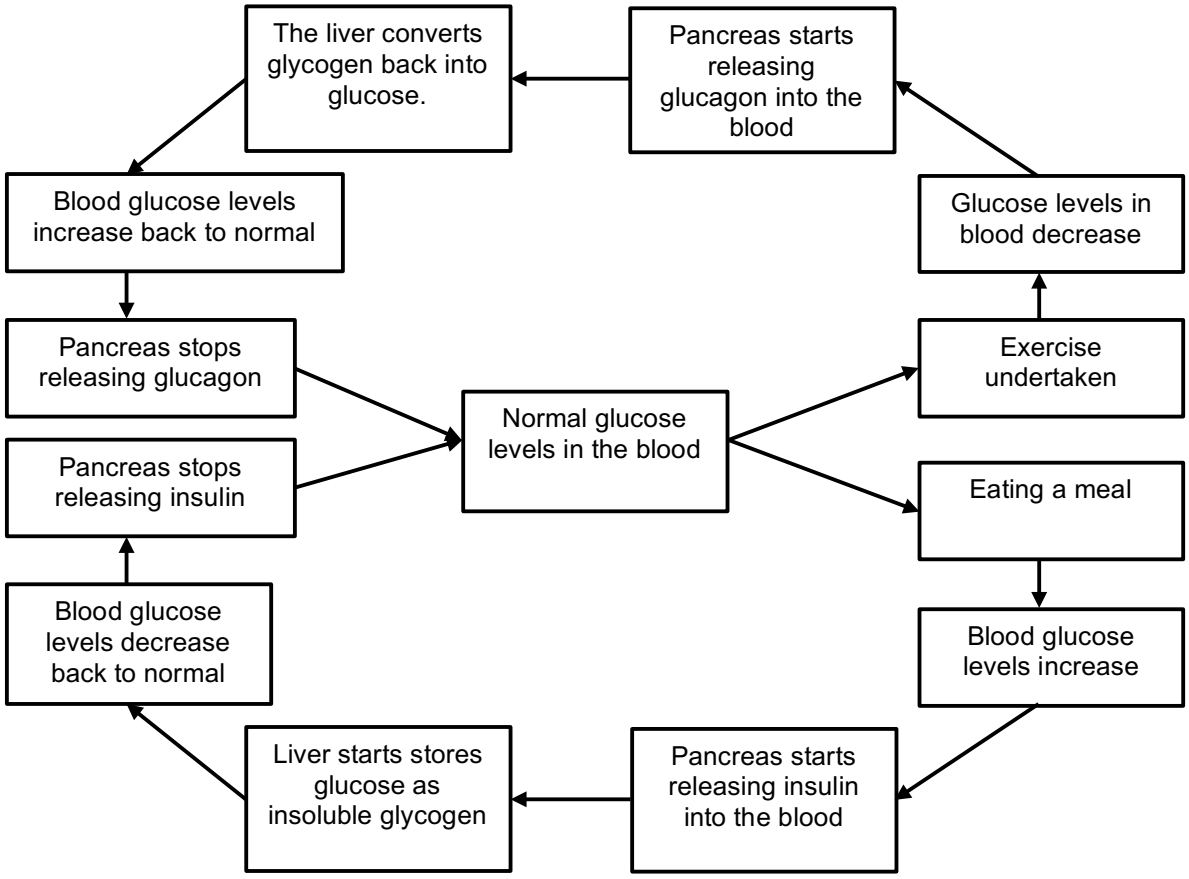


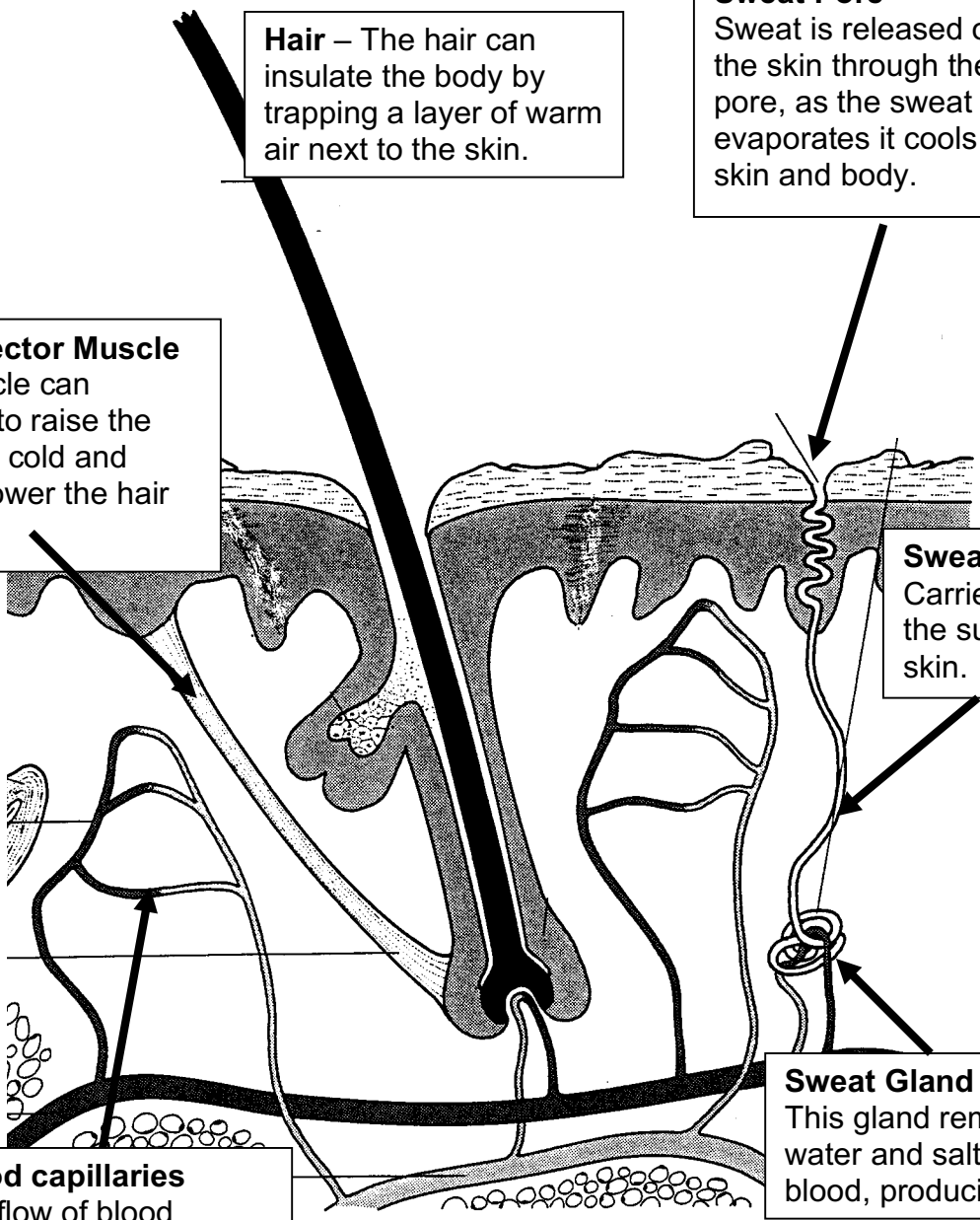
Fig.1 - Negative feedback mechanism

Control of Blood Glucose Levels - An Example of Negative Feedback



The Skin

The skin plays an important part in controlling body temperature.



Hair – The hair can insulate the body by trapping a layer of warm air next to the skin.

Sweat Pore
Sweat is released onto the skin through the pore, as the sweat evaporates it cools the skin and body.

(Hair) Erector Muscle
This muscle can **contract** to raise the hair when cold and **relax** to lower the hair when hot.

Sweat Duct
Carries sweat to the surface of the skin.

Sweat Gland
This gland removes water and salt from the blood, producing sweat.

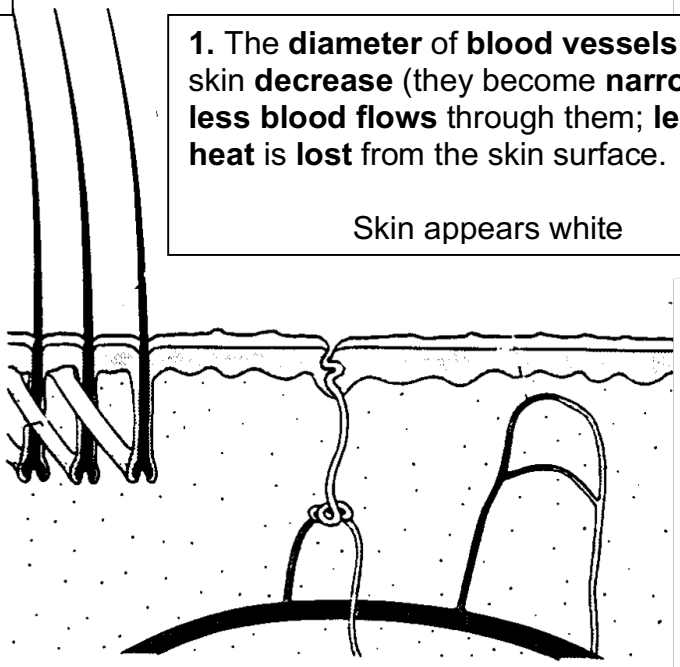
Blood capillaries
The flow of blood through the capillaries can be changed to help control heat loss from the skin.

Response and Regulation

When the body is cold

1. The **diameter** of **blood vessels** in the skin **decrease** (they become **narrow)**; **less blood flows** through them; **less heat** is **lost** from the skin surface.

Skin appears white

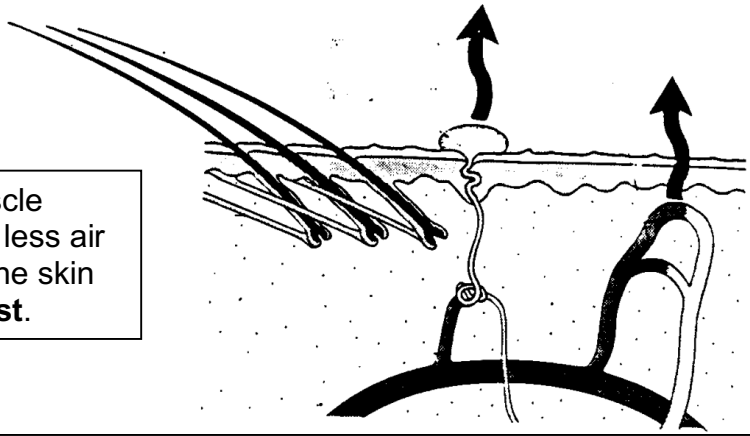


2. Hair erector muscles **contract;** hair stands up; layer of warm air trapped next to the skin helps **insulate** heat in the body.

3. Heat is released as muscles in the body contract causing **shivering**.

When the body is too hot

3. Sweat is released from the **sweat pores**; body **heat** is used to **evaporate** the sweat.



2. Hair erector muscle **relax;** hair lies flat; less air is trapped next to the skin so **more heat** is **lost**.

1. The diameter of the **blood vessels** in the skin increases (**get wider)**; **more blood flows** through them; **more heat** is **lost** from the skin surface.

Skin appears red

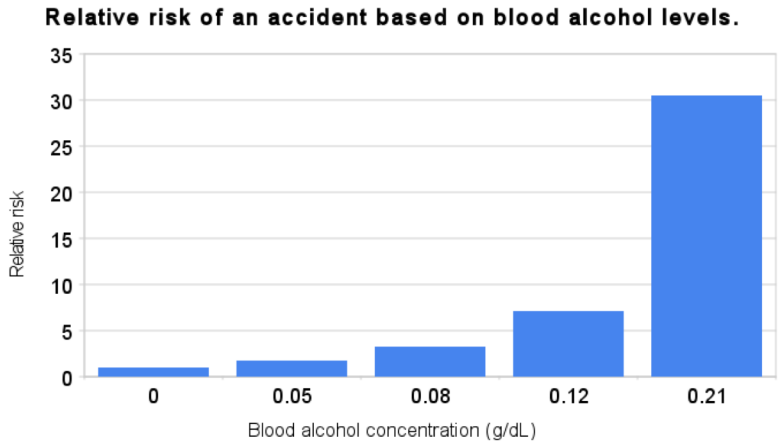
Lifestyle diseases – Drugs

A drug is any substance that alters your physical or physiological state.

Alcohol

Alcohol changes chemical processes in the body.

Short-term effects
Alcohol affects your nervous system by **slowing down your reactions** (this means that your **reaction time is increased**).



Long-term effects

- Some people may become dependent on, or addicted to alcohol.
- Alcohol can also cause long-term **physical damage**:
  - liver disease
  - circulatory
  - heart diseases

What does addiction mean?

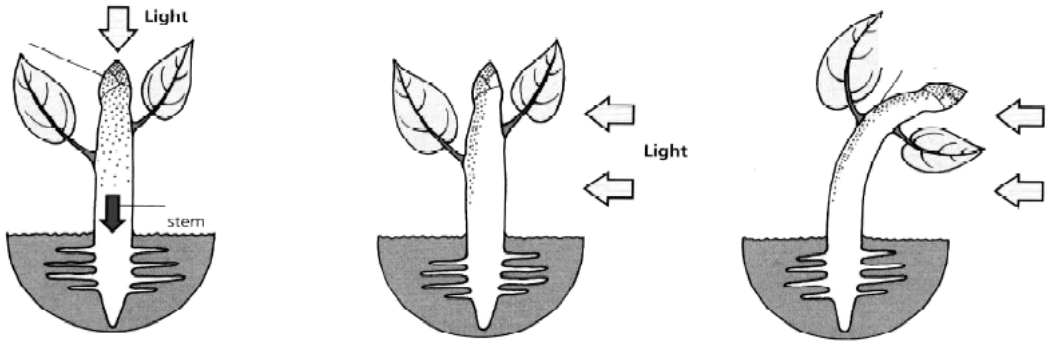
- An addiction is when people become dependent on a drug.
- A characteristic of addiction is that people will suffer withdrawal symptoms without the drug.

Plant Senses

Plants can sense light, and the pull of gravity and water.
They respond to these things by **growing** slowly in certain directions.
A **tropism** is the **growth** of a **plant** towards a **light source** or in response to a **source of gravity**.

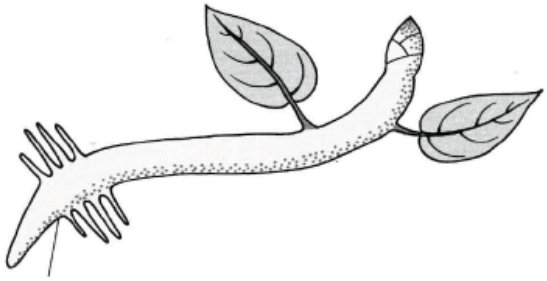
Phototropism: response to light

Plants need light to make food, so they respond to light by growing towards it **– positive phototropism.** They also turn their leaves to face the light. This makes sure leaves get as much light as possible for photosynthesis.



Gravitropism: response to gravity

Roots **grow** down in response to gravity - **positive gravitropism**.
This makes sure they find soil and water.
Shoots always **grow** up **– negative gravitropism**.
This makes sure they reach light.



Root growing down in response to gravity

Plant hormones regulate growth and other functions in plant cells.
A hormone called **auxin** controls a plant's responses to light and gravity.
The hormone is made at the tips of stems and roots. It speeds up growth in stems. It slows down growth in roots.

Homeostasis and the Kidneys

Homeostasis means keeping the internal environment constant

Conditions inside the body must be kept stable.

Examples to learn:

- **Water content** of the body must be kept constant,
- **Waste chemicals** must be removed from the body,
- **Body temperature** must remain constant,
- **Glucose levels** must remain constant.

The Kidneys

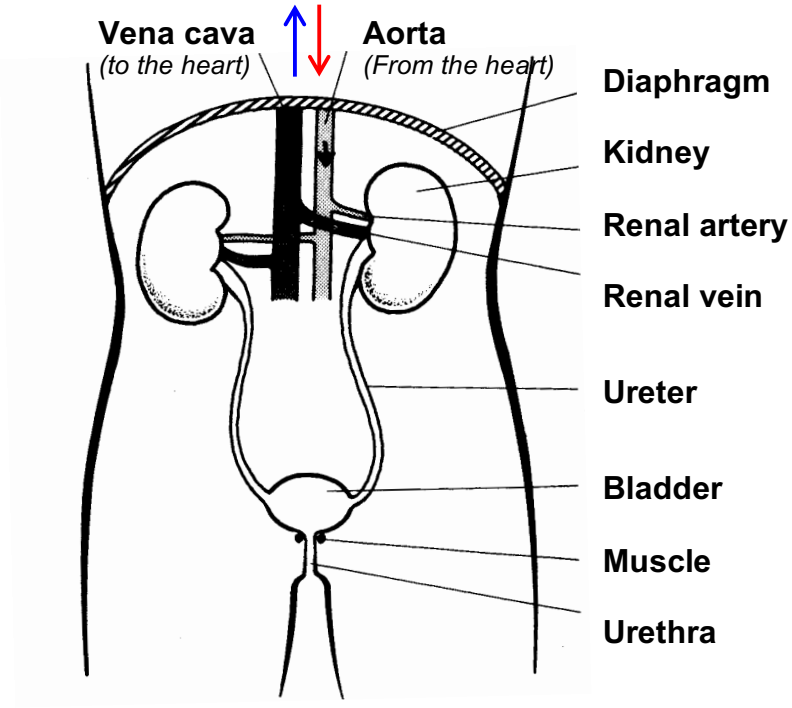
The kidneys have three functions in the body:

1. **Control of water content** of the blood.
2. **Removal of urea** from the blood.
3. **Removal of excess mineral salts** from the blood.

The process of **removing waste** from the body is called **excretion**.

Structure of the Excretory System

The kidneys are about 12 cm long and 7 cm wide and are located in the abdomen.



Facts to learn:

- Blood enters the kidney through the **renal artery**.
- Blood leaves the kidney through the **renal vein**.
- The **ureter** is a tube that carries urine from a the kidney to the bladder.
- The **bladder** stores urine.
- The **urethra** carries urine from the bladder out of the body,

Fig. 1 – Relative position of kidneys, bladder and main blood vessels.

Structure of the Kidney

The kidney consists of two layers:

1. Outer layer – Cortex.
2. Inner layer – Medulla.

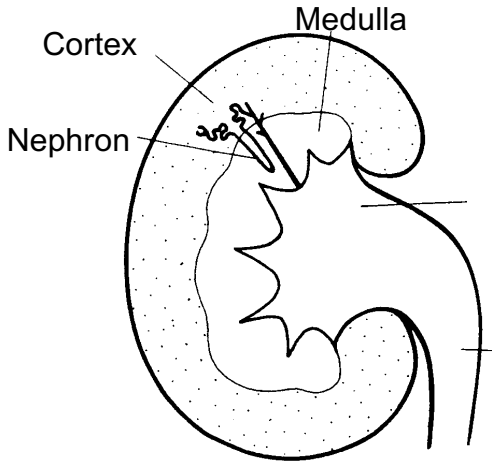


Fig. 1 Trans section of kidney

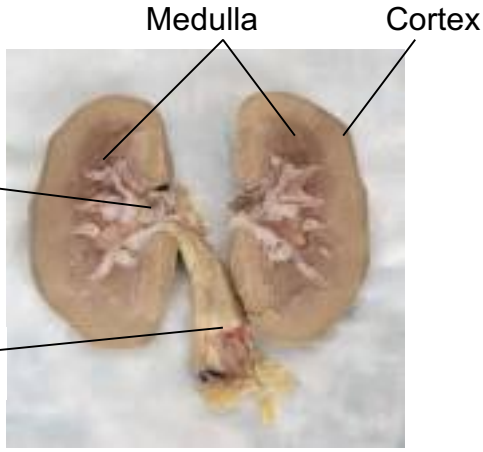
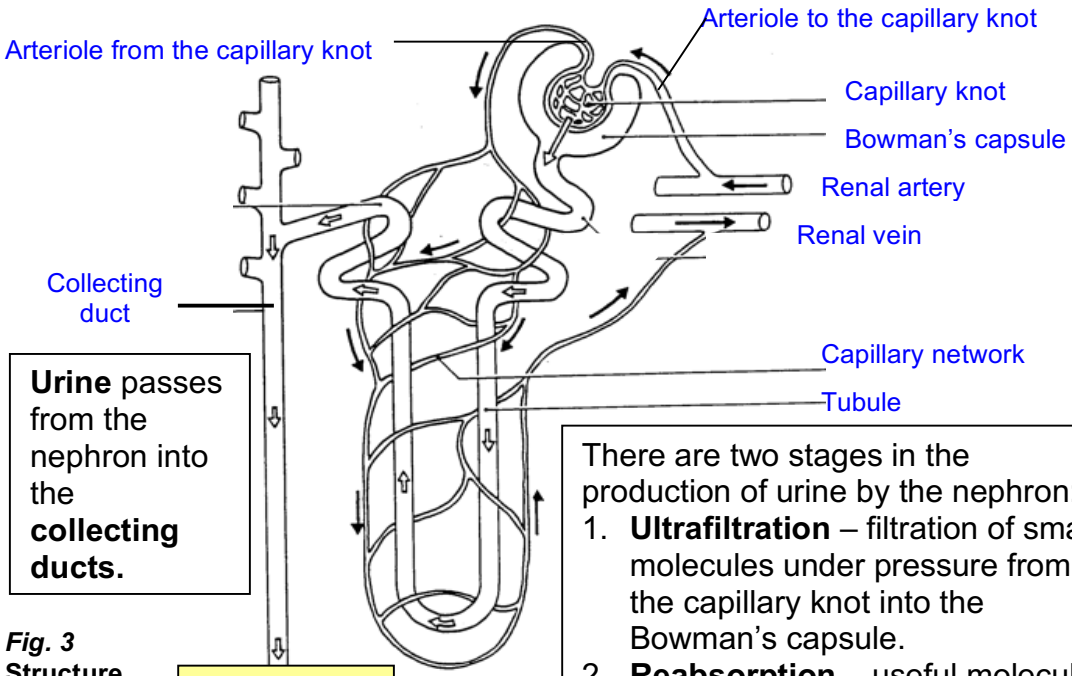


Fig. 2 Dissected pig's kidney

The Nephron

The nephrons remove urea, excess mineral salts and excess water from the blood to make urine.

There are approximately 1,000,000 nephrons in each kidney. **Fig. 1** shows their location across the cortex and medulla.



Urine passes from the nephron into the **collecting ducts.**

Fig. 3 **Structure of a nephron.**

Urine = water, urea and mineral salts

There are two stages in the production of urine by the nephron:

1. **Ultrafiltration** – filtration of small molecules under pressure from the capillary knot into the Bowman's capsule.
2. **Reabsorption** – useful molecules are reabsorbed back into the blood from the tubule.

Role of the Kidneys in Homeostasis (Biology Only)

How do the kidneys remove urea and excess mineral salts?

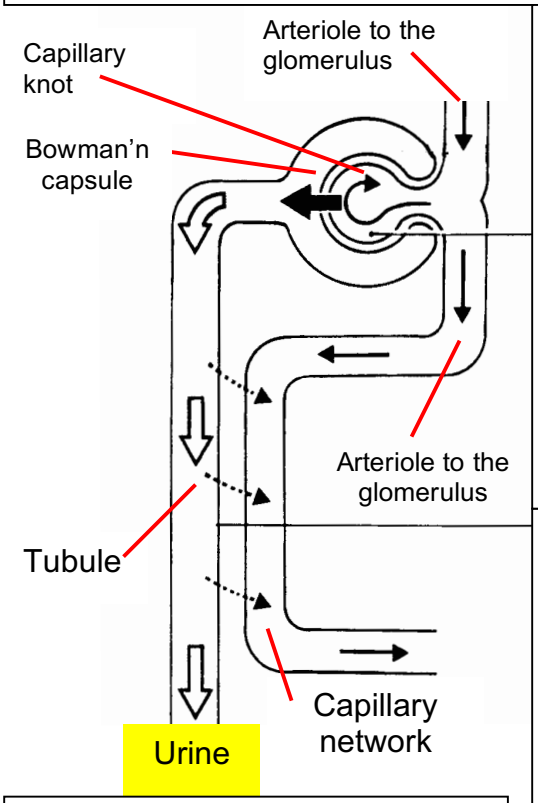


Fig. 1 Schematic drawing of the nephron.

Ultrafiltration

- The arteriole to the capillary knot has a larger diameter than the arteriole from the capillary knot, this increases blood pressure in the capillary knot.
- Small molecules such as urea, glucose, mineral salts, water and amino acids are filtered under pressure from the blood in the capillary knot into the Bowman's capsule.
- Large molecules, such as proteins, or red blood cells are too large to be filtered out of the blood.

Reabsorption

- Useful substances such as glucose and amino acids are reabsorbed from the filtrate in the tubule into the blood in the capillary network.
- Excess mineral salts are also reabsorbed.
- Water is also reabsorbed.

The table shows some differences in the composition of blood plasma and urine:

Substance	Blood plasma (%)	Urine (%)
Protein	9.00	0
Glucose	0.10	0
Urea	0.02	2.00
Mineral Salts	0.75	1.25

Analysis of table:

- There is **no protein** in the urine because their **molecules** are **too large to be ultrafiltrated** from the capillary knot into the Bowman's Capsule.
- There is **no glucose** in the urine because it **has all been reabsorbed** from the tubule **back into the blood** of the capillary network.
- The **percentage of urine and mineral salts has increased** because some of the **water** in the tubule has been **reabsorbed**, therefore making the filtrate flowing into the collecting duct more concentrated.

The presence of blood or cells in the urine would indicate kidney disease.

Role of the Kidneys in Homeostasis (Biology Only)

Water Balance

The volume of water you take in has to equal the volume of water you lose.

We gain water:

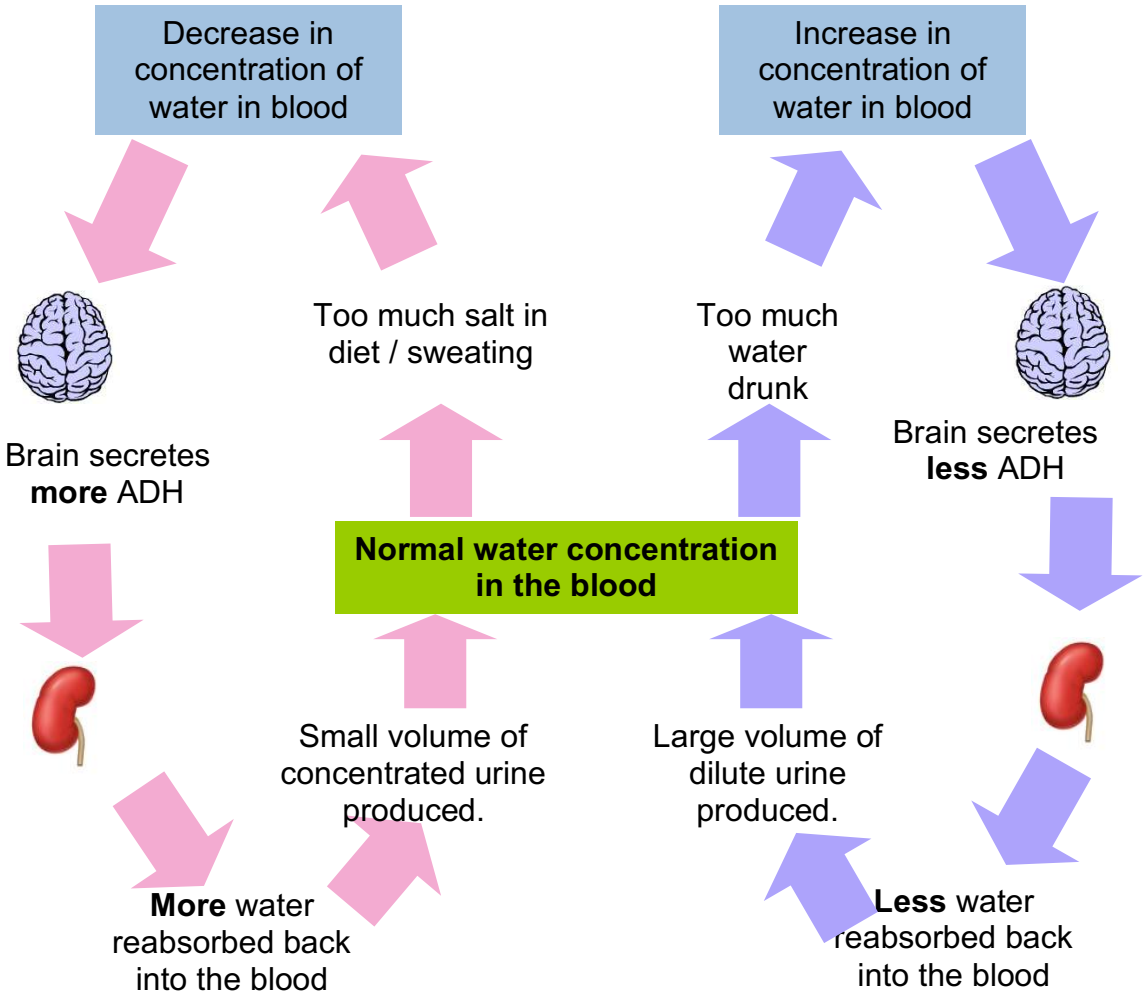
- in food
- by drinking
- metabolic water (made during respiration)

We lose water:

- when exhaling
- by sweating
- in urine
- in faeces

Osmoregulation = controlling water concentration in the blood

The brain monitors the concentration of water in the blood. Osmoregulation is controlled by the **anti diuretic hormone (ADH)**. It is released by the brain and is carried by the blood to the kidneys. The flow chart below summarises the process:



Kidney Failure

Kidney failure is a common disease that affects tens of thousands of people each year. It is possible to live after one kidney has failed, but if both fail, without treatment, the patient will die. It is possible to treat kidney failure by **kidney dialysis** or by **organ transplant.**

Dialysis

Dialysis restores the concentrations of dissolved substances in the blood to normal levels.

How does a dialysis machine work?

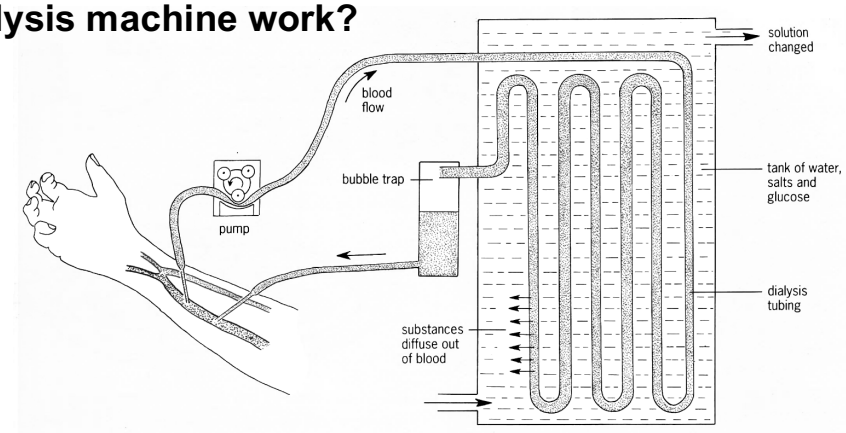
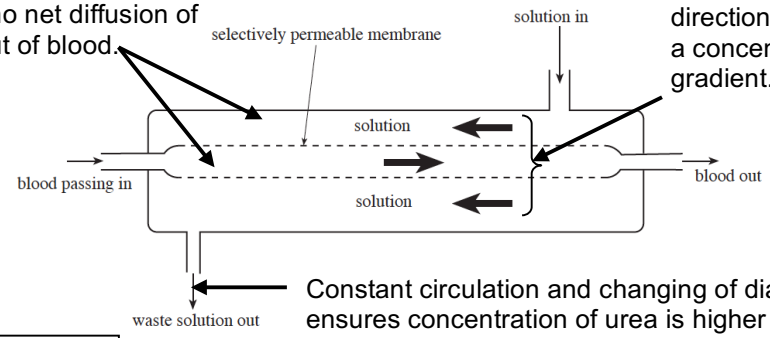


Fig. 1 Illustration of a dialysis machine.

The patient's blood flows between semi permeable membranes (the dialysis tubing). To ensure that useful substances such as glucose and salts are not lost from the blood (by diffusion through the pores of the dialysis tubing), the dialysis fluid contains the same concentration of useful substances as the blood plasma. This ensures that only urea, and excess of mineral salts and water will diffuse into the dialysis fluid. Dialysis treatment needs to be carried out regularly.

Equal concentration of useful substances, e.g. glucose; therefore no net diffusion of glucose out of blood.

Blood and dialysis fluid flow in opposite directions to maintain a concentration gradient.



Constant circulation and changing of dialysis fluid ensures concentration of urea is higher in the blood.
Urea therefore diffuses out of the blood into the dialysis fluid.

Fig. 2 Schematic illustration of a dialysis machine.

Transplantation

The donor kidney is implanted at the bottom of the abdomen close to the thigh and is connected to the blood supply of the recipient. The failed kidneys are not normally removed.

To **reduce the chance of rejection before** a transplant:

- Doctors make sure that the **'tissue type'** of the **donor** and the **recipient** need to be **similar**. (Close family members are more likely to have a similar tissue type to the recipient.)

To **reduce the chance of rejection after** a transplant:

- The donor must take drugs that suppress the immune system.

Comparing the advantages and disadvantages of dialysis and a kidney transplant:

Dialysis	**Kidney transplant**
Temporary treatment	Potential to 'cure' problem for many years.
Diet restrictions	Generally, no restriction to diet after treatment
Patient must visit hospital several times a week for treatment.	Patient does not have to visit hospital every week
Non-invasive treatment	Treatment involves major surgery
No drugs needed	Patient must take drugs to suppress immune system
No problems with rejection of treatment	New kidney may be rejected by the body.

Kidney Transplants – ethical Issues

There are a number of ethical issues involved with transplants. Some to consider are:

- Xenotransplants
- Kidney donor schemes, e.g. presumed consent in Wales
- Living donors
- Buying and selling of organs
- Availability of dialysis machines.

Growing Bacteria

Bacteria and fungi can be grown in Petri dishes containing nutrient agar. Working safely with microbes requires the use of **aseptic techniques** - this **prevents microbes from the air contaminating the culture or microbes from the culture contaminating the air.**

Investigating the presence of bacteria in milk using agar plates

Method

1. Sterilise Petri dishes and nutrient agar before use, e.g. in an autoclave/pressure cooker at 121^{O}C for 15 minutes - to kill any bacteria in the agar.
2. Use an incubating loop to transfer a sample of milk to the Petri dish. The loop should be sterilised before and after the transfer by heating the loop until it glows red in a Bunsen flame, to kill all the micro-organisms.
3. Wipe the surface of the agar with the inoculating loop.
4. Secure the lid of the Petri dish with strips of adhesive tape, to prevent micro-organisms from entering or escaping.
5. Incubate the agar plates at 25^{O}C to allow the bacteria to grow - pathogens will not grow at this temperature.
6. After 48 hours examine the dishes and count the number of colonies present.
7. Record your results.
8. Repeat the experiment.
9. Repeat steps 1 – 8 using different milk samples.
10. Compare the results.
11. The Plates and equipment should be sterilised after use

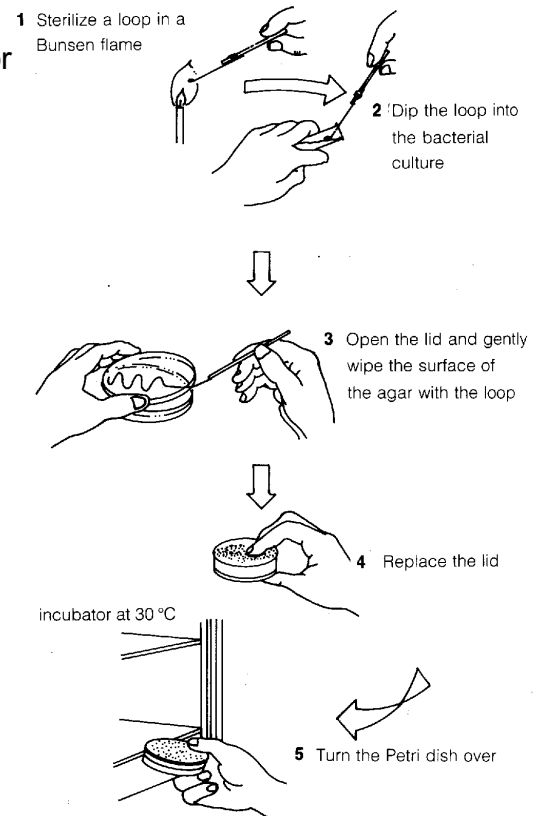


Fig. 1 Culturing of bacteria using aseptic techniques.

Result

A single bacterium is too small to be counted when it is placed on the agar plate.
Each bacterium grows into a **colony**. The colonies can be counted to find out the original numbers of bacteria.

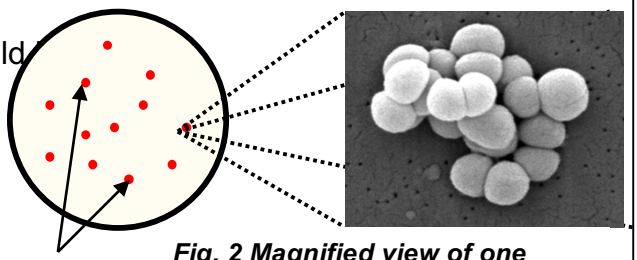
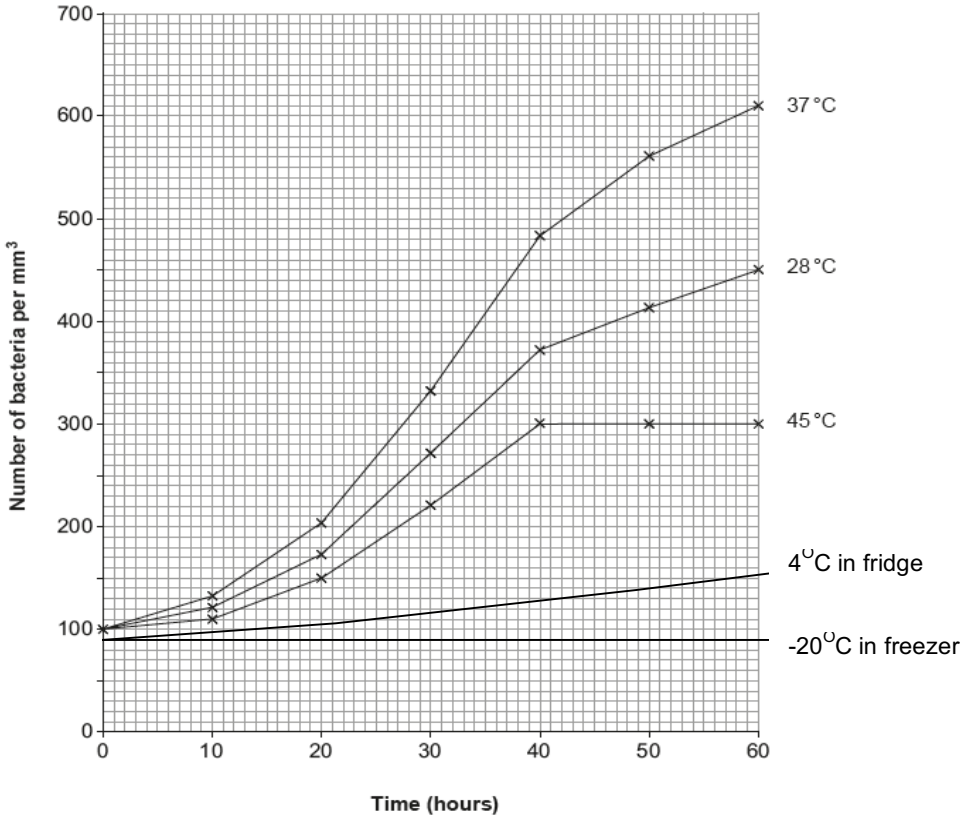


Fig. 2 Magnified view of one bacterial colony. This investigation assumes that each colony has grown from an individual bacterium in the original culture.

Investigating the effect of temperature on the growth of bacteria

The graph below shows the growth of the bacterium *Micrococcus luteus* at different temperatures:



Description

- As the temperature increases the number of bacteria increases up to 37^{O}C.
- Above 37^{O}C as the temperature increases the number of bacteria begin to decrease.

Explanation

- Cell metabolism (chemical reactions in cells) is controlled by enzymes.
- Increasing temperature increases the rate of enzyme-controlled reactions therefore growth and reproduction of bacteria speeds up.
- Above 37^{O}C the enzymes in cells begin to denature and therefore growth and reproduction of bacteria slows down.

Application in Food Storage

- Most refrigerators are kept at 4^{O}C. At this temperature bacteria reproduce only very slowly, but they are not killed. The activity of any enzymes in the food is also slowed down.
- The temperature of -20^{O}C in the freezer stops the growth and reproduction of bacteria, but it still does not kill them.

Penicillin

Penicillin is a type of antibiotic that is produced by the fungus *Penicillium*. It was first isolated in 1928 by Alexander Fleming from contaminated Petri dishes. He succeeded in extracting some of the fungus and used it to treat an infected wound. He called this extract **penicillin**. The technology at that time was too limited to allow him to culture and study the fungus successfully, so he saved the culture and moved on to a different research field.

These days the fungus *Penicillium* is grown in **fermenters** and the penicillin is extracted from them.

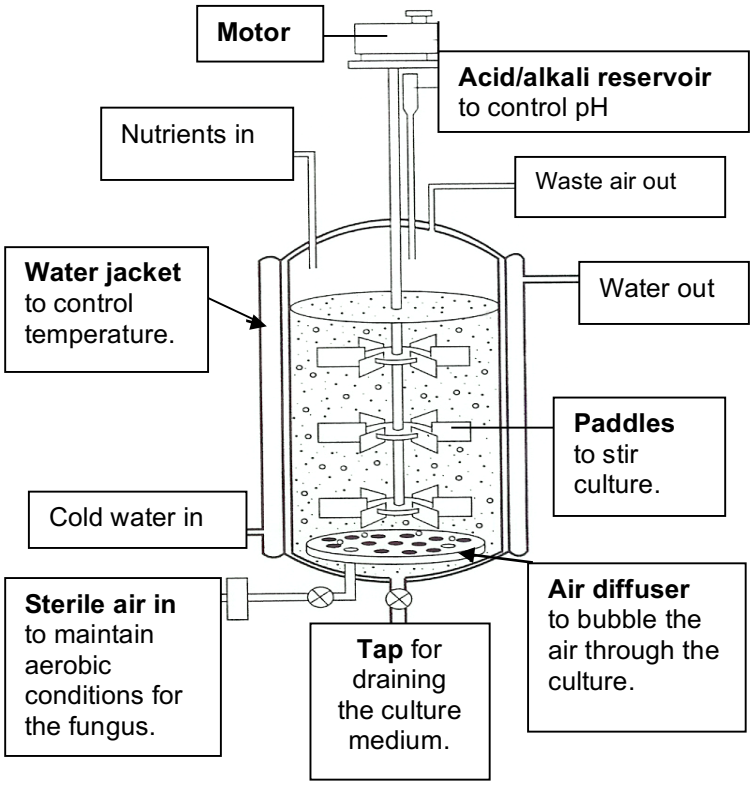


Fig. 1 Typical plan of a fermenter used to produce Penicillin.

The Process

1. A starter culture of *Penicillium* is added to a culture medium containing nutrients in a fermenter.
2. The fermenter allows fine control of the air supply, temperature and pH to ensure optimal growth by the fungus.
3. The fungus grows and secretes the antibiotic into the culture medium.
4. When the incubation comes to an end the culture medium is filtered and the penicillin is extracted from the filtrate.

Pathogens

Most micro-organisms are harmless and many play an essential role in recycling nutrients in the environment (e.g. nitrogen cycle and carbon cycle).
Some can cause diseases (**pathogens**); others are useful (produce antibiotics).

A pathogen is a disease causing micro-organisms.
Examples of pathogens are:

- bacteria
- viruses
- protists
- fungi

Bacteria

It is believed that some bacteria are the oldest forms of life.

- A bacterial cell contains cytoplasm, cell membrane and cell wall.
- There is no obvious nucleus, only a strand of circular DNA.
- Bacteria reproduce by dividing in two to form clones.

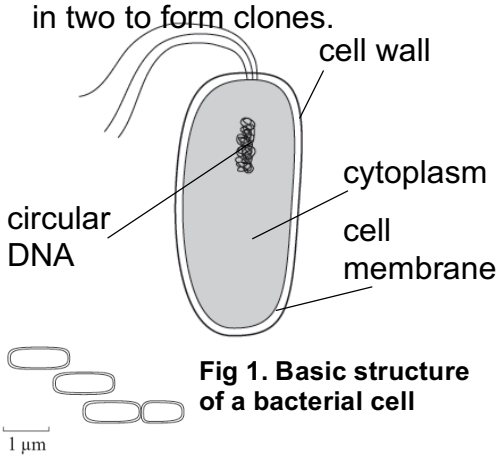


Fig 1. Basic structure of a bacterial cell

Viruses

- Viruses are smaller than bacteria.
- They contain a protein coat surrounding a number of genes.
- They can only reproduce in a host cell.
- Producing new viruses destroys the host cell as the new viruses are released. They are then free to attack other cells.

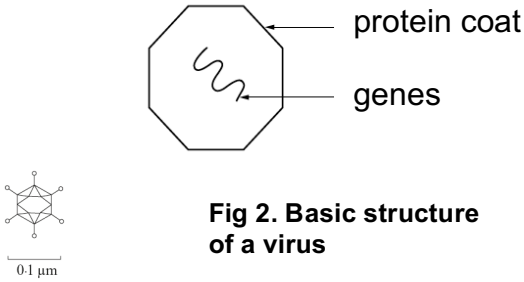


Fig 2. Basic structure of a virus

Communicable diseases

The means by which bacteria, viruses and fungi can be spread are as follows:

- contact,
- aerosol,
- body fluids,
- water,
- insects,
- contaminated food.

Disease, Defence and Treatment (Biology Only)

AIDS (Acquired Immune Deficiency Syndrome)

Causative agent	HIV (Human Immunodeficiency Virus). The virus infects lymphocytes which are part of the body's immune system.
How it is spread	Blood to blood contact, especially during sexual intercourse.
Effect on infected organism	Without immunity, the body can become infected with a variety of micro-organisms, e.g. tuberculosis or pneumonia.
Prevention / treatment	• Use of condoms • Use of disposable gloves should be used where there is any danger of contact with contaminated blood. • Antiviral agents can be used, but they only prevent the multiplication of the virus inside cells and must be taken throughout life.

Chlamydia - the most common sexually transmitted disease in Britain

Causative agent	The bacterium *Chlamydia trachomatis*
How it is spread	During sexual intercourse via the vagina and urethra.
Effect on infected organism	If left untreated, it could cause • infertility in adults, • conjunctivitis in babies during the process of birth if the mother is infected. It can also spread to the baby's lungs.
Prevention / treatment	Can be **prevented** by the use of condoms. Can be **treated** with antibiotics such as tetracycline or erythromycin.

Malaria - kills over a million people in the world each year.

Causative agent	The single celled organism – *Plasmodium*.
How it spreads	*Plasmodium* is spread via female mosquitoes of the genus *Anopheles*. *Anopheles* mosquitoes bite humans and inject *Plasmodium* into the blood stream.
Effect on infected organisms	*Plasmodium* causes a fever when it destroys red blood cells in humans.
Prevention / treatment	Prevention methods include: • killing mosquitoes with insecticide, • releasing large numbers of infertile male mosquitoes, • biological control of mosquitoes, • use of mosquito nets and repellents. Treatment consists of: • killing *Plasmodium* with anti-malarial drugs, such as • paludrine or daraprim. • A vaccine against *Plasmodium* has been developed.

Defending Against Infection

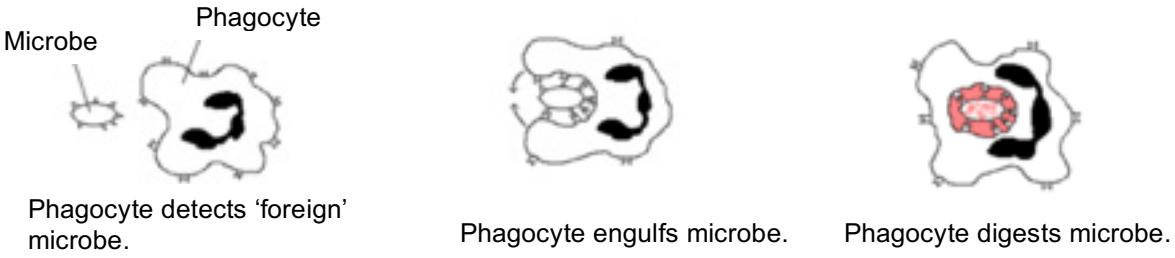
Your body has three lines of defence against infection by pathogens:

1. **The skin stops microbes getting into the body.**
   - A layer of dead cells form a barrier around the body.
   - There is also a community of microbes on the skin (the skin flora), that makes it difficult for pathogens to become established on the skin surface.

2. **Platelets stop microbes getting into the body through a cut.**
   - Platelets clot the blood in a cut and form a scab, keeping out microbes.

3. **White blood cells defend against microbes that are inside the body.**
   White blood cells defend against microbes in three ways:

   a. **Phagocytes Ingest bacteria.**

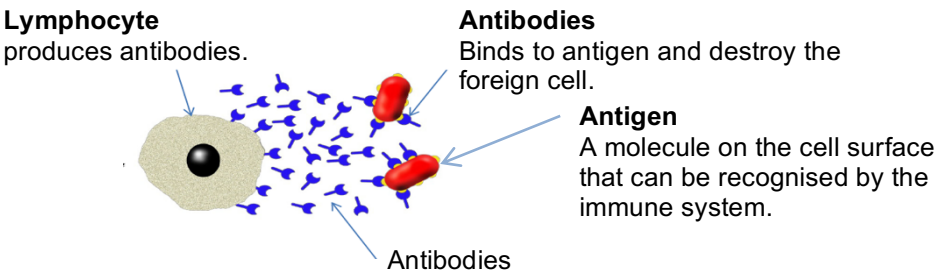


Phagocyte detects 'foreign' microbe.

Phagocyte engulfs microbe.

Phagocyte digests microbe.

   b. **Lymphocytes produce antibodies to inactivate bacteria or viruses.**

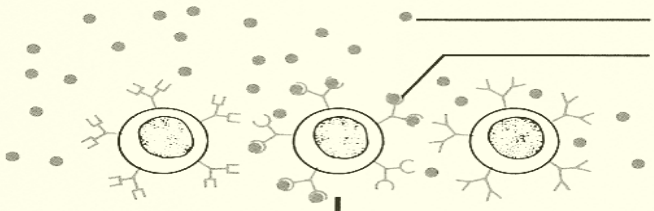


   c. **Lymphocytes produce antitoxins that counteract toxins released by bacteria.**

The Immune Response

All cells have unique **proteins** on their surface called **antigens**.
The immune system will recognise any cells as '**foreign'** if their **antigens are different to** the ones on **body cells**.
'Foreign' antigens **stimulate** an **immune response** by the body.

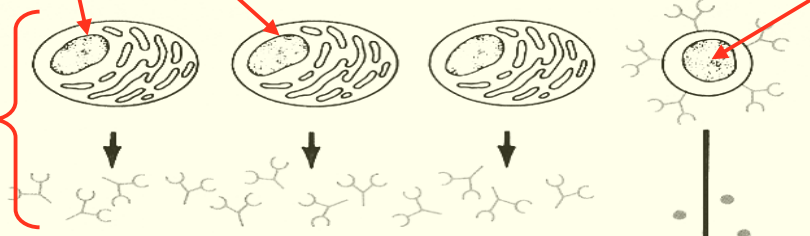
Primary Response



2. Clones differentiate. Most develop to form short lived **plasma cells.**

Lymphocytes multiply to form clones.

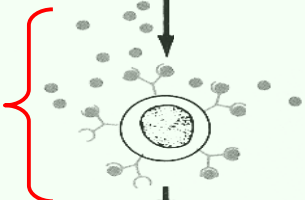
4. Some clones develop into long lasting **memory cells.**



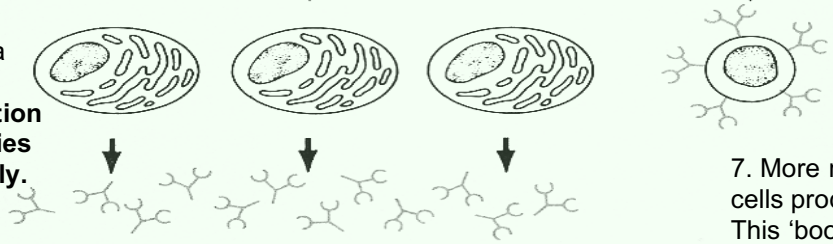
3. Plasma cells produce antibodies that will destroy cells carrying the specific 'foreign' antigen.

Secondary Response

5. Memory cells are long lasting and if they come across the same **specific antigen** again they stimulate an immune response.



6. Large numbers of **plasma cells** develop producing a **large concentration of antibodies very quickly.**

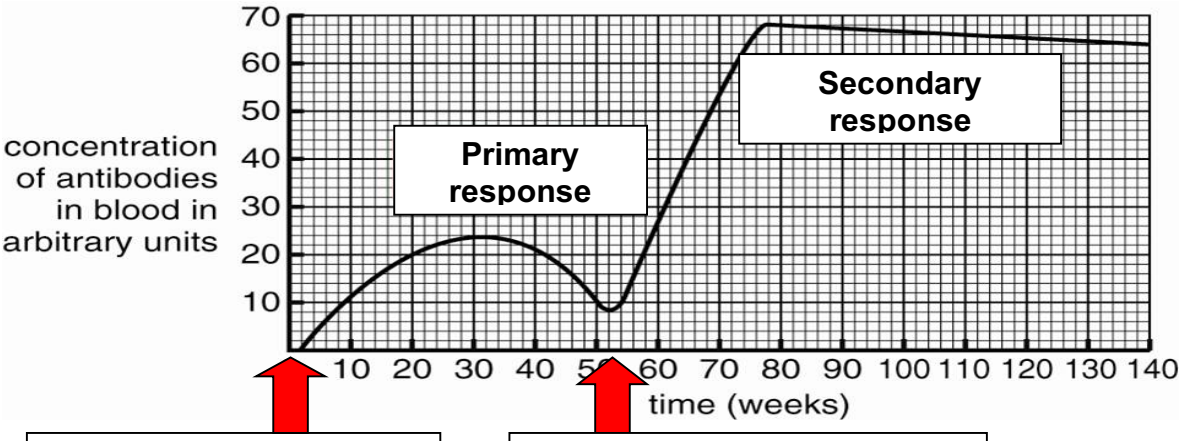


7. More memory cells produced. This 'boosts' immunity.

Immunity

Memory cells remain in the body and antibodies are produced very quickly if the same antigen is encountered a second time.
This memory provides immunity following a natural infection and after vaccination.
The response is highly specific to the antigen involved.

The graph below shows the body's immune response when it comes across an antigen for the first and second time:



Body encounters '**specific antigen'** for the **first time** stimulating an immune response.

Memory cells encounter the same 'specific antigen' stimulating an immune response.

Describing the differences between the primary and secondary response:

1. The primary response is relatively slow, with a delay before antibody production, compared to the secondary response that is much faster.
2. The concentration of antibodies produced in the secondary response is much higher compared to the primary response.
3. The concentration of antibodies stays higher for much longer in the secondary response compared to the primary response.

Explanation of differences

The presence of memory cells able to detect a 'specific antigen' causes antibodies to be produced very quickly and in large numbers if the same antigen is encountered a second time – this is known as **immunity**.

Why do most people suffer from measles only once, but could suffer from flu many times during their lives?

The 'flu' virus **mutates rapidly** giving rise to new strains with **different antigens**. Because of this, **different antibodies are needed** and the memory cells produced during the previous bout of 'flu' cannot recognise the new antigens. The body therefore is **not immune** to the new strain of 'flu'.

Vaccination

A Historical Perspective

Edward Jenner first used vaccination against smallpox.
He had heard that milkmaids who suffered the mild disease of cowpox never seemed to catch smallpox, a disease that caused many deaths at the time, particularly among children.
He suggested that the pus in the blisters that milkmaids received from cowpox protected them from smallpox.
In 1796, he inoculated a healthy boy with pus taken from a cowpox spot and the boy caught cowpox. A few weeks later Jenner inoculated the boy again, this time with smallpox.
Fortunately for Jenner his theory proved correct and the boy survived.
Jenner's methodology would be considered unethical these days.

How does vaccination work?

Some pathogens can make you seriously ill before the immune system gets a chance to respond. Getting vaccinated against these diseases can greatly reduce the possibility of dying or suffering permanent harm because of these diseases.
It's possible to get immunized against diseases by **introducing a small amount of dead or inactive pathogens into the body**.
The antigens on these pathogens will cause the lymphocytes to produce antibodies to destroy the pathogens. The immune system will also produce memory cells that will recognise the specific antigens if they enter the body again causing large numbers of antibodies to be produced rapidly.

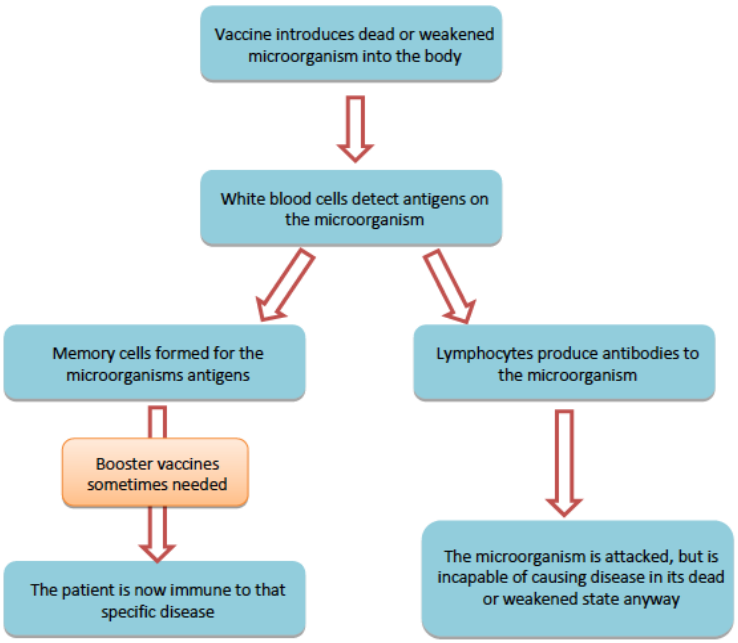


Fig.1 Flow chart illustrating vaccination.

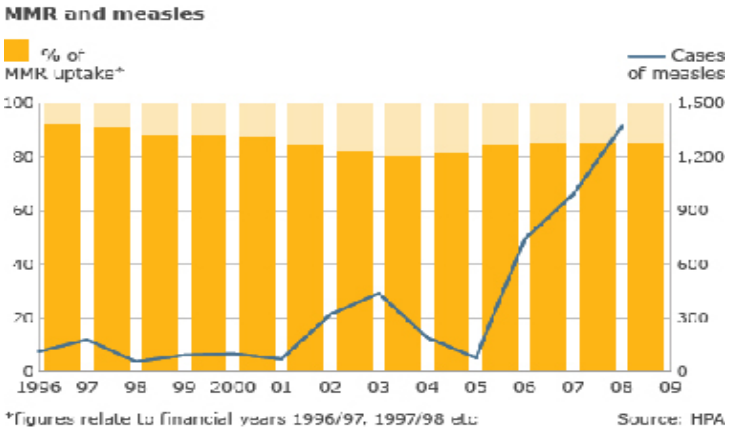
Are vaccinations Safe? The MMR Story

The MMR (measles, mumps and rubella) is a vaccination that protects against measles, mumps and rubella (German measles). Measles and mumps can cause brain damage and even death. Rubella (German measles) can damage unborn babies. After the MMR vaccine was introduced the number of cases of these diseases fell until almost no children died of measles or mumps.

In February 1998, Dr Andrew Wakefield published a paper in the medical journal *The Lancet*. His research suggested that there was a link between the MMR vaccine and autism in children.

The story drew a lot of interest from the media. People got worried and the number of children vaccinated with the MMR fell.

Graph 1
As uptake of MMR fell the cases of measles increased.



By 2001 the percentage of children vaccinated fell from 92% to 75%. This percentage of vaccination is not enough to support herd immunity in the population.

How confident can we be with the validity of the research?

- The study included only twelve children.
- Dr Wakefield was paid £55 000 by the parents of some of the children to help them prepare evidence against the MMR vaccine for a court case.
- Dr Wakefield had also been developing some treatments for measles that would not have been used if people had more faith in the MMR.

How can reproducing research be of value?

- A large number of separate studies have been carried out since 1998.
- Thousands of children have been studied.

The conclusion drawn from these studies have shown that there is **no link between the MMR vaccine and autism in children**.

This conclusion is based on thousands of repeat experiments and reproducing research by separate research groups, and therefore is far more valid.

Unfortunately, children have been harmed and a number have died as a result of poor research and irresponsible reporting by the media.

Antibiotics

An antibiotic is a substance produced by a microorganism to kill other microorganisms. (e.g. Penicillin from the fungus *Penicillium*)

Antibiotics, including penicillin, were originally medicines produced by living organisms, such as fungi. Antibiotics help to cure bacterial disease by **killing the infecting bacteria** or **preventing their growth**.

Antibiotics do not kill viruses, because viruses live inside the host's cells and so an antibiotic cannot reach them.

Antibiotic Resistance

Resistance to a chemical poison is the ability of an organism to survive exposure to a dose of that poison which would normally be lethal to it.

Antibiotic resistant bacteria can evolve by the overuse of antibiotics such as:

- Use of antibiotics in animal feed,
- Over-prescription by doctors.

Doctors are worried about resistance to antibiotics because some bacteria, e.g. *E. coli* are common in humans and can cause serious illness or even death.

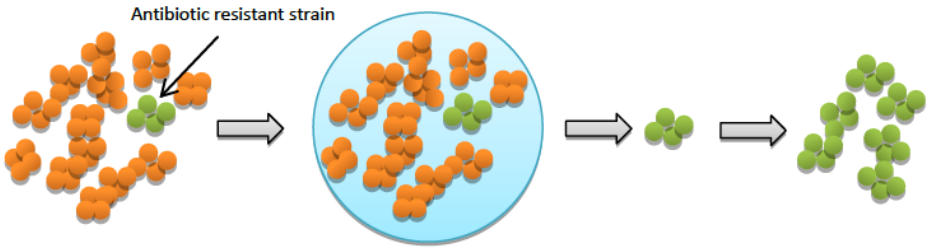


Fig. 1 How antibiotic resistance develops.

Staphylococcus bacteria naturally include some strains that are resistant to some antibiotics

The bacteria are exposed to multiple doses of antibiotic over a period of time

The non-resistant bacteria are killed by the antibiotic

The resistant strain reproduces and becomes much more common than before

MRSA (Methicillin resistant *Staphylococcus aureus*) has developed resistance to several antibiotics. Antibiotics are widely used in hospitals, especially to prevent infections occurring from surgery. The bacteria originated in Australia and within ten years had spread world-wide.

Methods used in hospitals to control MRSA are:

- Hand washing,
- Thorough cleaning of hospital wards,
- Use of alcohol gels or antibacterial gels,
- MRSA screening before surgery.

Health

Health is not just the absence of illness. It is a positive and enjoyable feeling of well being resulting from efforts to maintain an all-round state of physical and mental fitness.

Health is **affected** by a variety of factors:

- Diet,
- Living conditions,
- Contact with infections,
- Your genes,
- Lifestyle.

Poor health can be **prevented** by:

- Good hygiene,
- Clean water,
- Improved diet,
- Vaccination.

Keeping Healthy
Keeping fit helps our bodies to function better. Sustained regular exercise improves our blood circulation and reduces our heart rate. It also makes the breathing system more efficient.

Some conditions can be **treated** by:

- Drugs such as antibiotics,
- Organ transplants,
- Chemotherapy,
- Radiotherapy,
- Gene therapy.

It is important to remember that science and technology may provide the answer to some health problems but not all.

Use of Animals for Testing Drugs.

All drugs may have side effects. New drugs may cause side effects that do not show up until **lots of people** use them. Large scale testing is required before new drugs are released on the market. Part of this testing involves using animals.

The reasons **animal-rights groups oppose** testing drugs on animals

- Laboratory animals are so different from humans that they do not react to drugs in the same way as humans do.
- Humans do not have the right to subject animals to any form of experimentation.

Scientists use these reasons to justify their work on animals:

- Humans should never have their lives threatened by experimental procedures.
- Testing on individual cells from tissues does not reflect the complexity of living organisms.
- Computer simulation are not accurate enough to model all the biological processes that take place in living organisms.

Discovery and Development of Potential New Medicines

A potential new drug has to go through several stages of testing before it can be licensed for use.

Pre-clinical stages

1. The drug is tested on human cells grown in the laboratory.
2. The drug is tested on animals, which are monitored for side effects.
3. The drug is then tested on healthy human volunteers to establish the correct dose for the drug.

Clinical stage

4. The drug is then tested on small groups of patients who are affected by the condition the drug is targeting.

If a drug successfully passes all these stages it can then be licensed for general use.

The process of developing new drugs is **expensive** and **time consuming**.

Human Drug Trials

In human drug trials, volunteers are put into two groups at random.
One group receives the drug being tested and the other group (the control group) will receive a **placebo.**

A placebo is a fake drug that has no effect on the body. Its purpose is to show that the observed results are due to the effects of the drug and not the psychological expectations of the individual.

The two most common type of drug trials are:

- **Blind trials**

  The volunteers do not know which group they are in but the researchers do. However, the researchers may unintentionally give away clues to the volunteers as to which group is receiving the drug or the placebo

- **Double-blind trials**

  The volunteers do not know which group they are in, and neither do the researchers, until the end of the trial. This removes the chance of bias and therefore increases the strength of evidence for the results from the trials.

Producing Monoclonal Antibodies

Monoclonal antibodies are produced from activated lymphocytes which are able to divide continuously, producing very **large numbers** of **identical antibodies**, **specific to one antigen**.

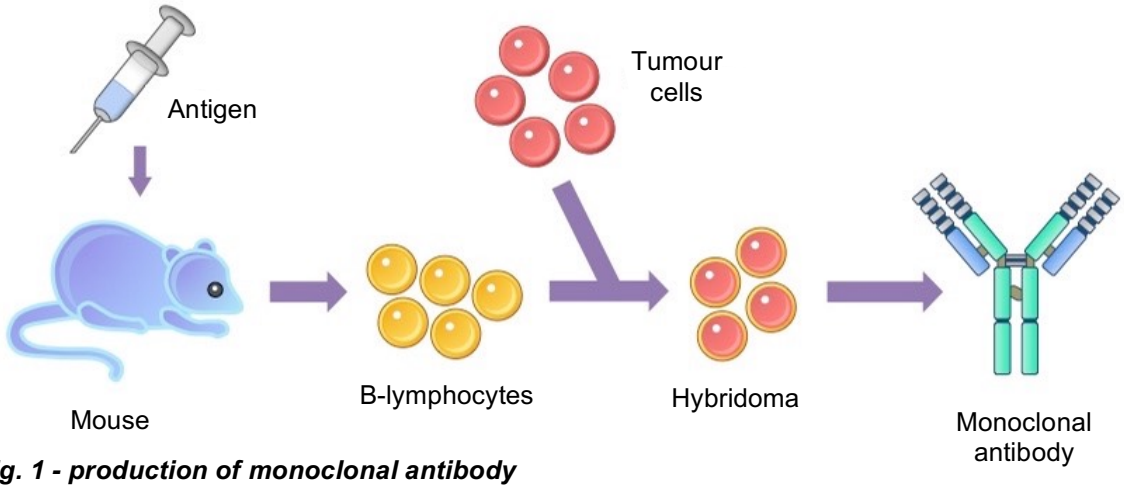


Fig. 1 - production of monoclonal antibody

Medical Uses of Monoclonal Antibodies

Medical use	Description
Diagnosis of diseases including Chlamydia and HIV	Immunoassays are used - labelled (via radioactivity or fluorescence) monoclonal antibodies are added to test samples of infected body fluids and attach to specific antigens. The extent of the infection is related to the extent of the labelling.
Tissue typing for transplants	The concentration of non-self-antigens in tissues is assessed. Monoclonal antibodies can be used against helper T-cells (T-lymphocytes) so B-lymphocytes, normally causing rejection, are prevented from functioning.
Monitoring the spread of malaria	Blood is taken from samples of people (even if they do not show any malarial symptoms) and tested with labelled monoclonal antibodies. Monoclonal antibodies will detect the presence of *Plasmodium* in the bloodstream (even if they are dead - killed by antimalarial drugs) as they have specific antigens and will attach to the labelled monoclonal antibodies. This enables the success of anti-malarial drugs and the potential spread of malaria to be monitored.
Supporting chemotherapy for cancers	The destruction of cancer cells can be targeted with the use of monoclonal antibodies. Some types of cancer cells have specific antigens called tumour markers. Monoclonal antibodies can be produced that act against tumour markers. If these are attached to anti-cancer drugs, they will deliver the drug directly to the cancer cells.