# BIOLOGY-PAPER 2

## 4.5 Homeostasis and response

Cells in the body can only survive within narrow physical and chemical limits. They require a constant temperature and pH as well as a constant supply of dissolved food and water. In order to do this the body requires control systems that constantly monitor and adjust the composition of the blood and tissues. These control systems include receptors which sense changes and effectors that bring about changes.
The function of the nervous system is to bring about fast responses. The hormonal system usually brings about much slower changes. Hormonal coordination is particularly important in reproduction since it controls the menstrual cycle. An understanding of the role of hormones in reproduction has allowed scientists to develop not only contraceptive drugs but also drugs which can increase fertility.

### 4.5.1 Homeostasis

Homeostasis is the regulation of the internal conditions of a cell or organism to maintain optimum conditions for function in response to internal and external changes.
Homeostasis maintains optimal conditions for enzyme action and all cell functions.
In the human body, these include control of:

- blood glucose concentration
- body temperature
- water levels

These automatic control systems may involve nervous responses or chemical responses.
All control systems include:

- cells called receptors, which detect stimuli (changes in the environment)
- coordination centres (such as the brain, spinal cord and pancreas) that receive and process information from receptors
- effectors, muscles or glands,

### 4.5.2 The human nervous system

**Structure and function**

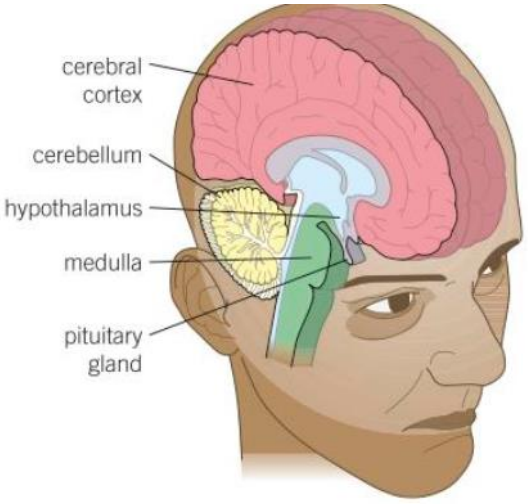
The structure of the nervous system is adapted to its functions.
The nervous system enables humans to react to their surroundings and to coordinate their behaviour.
Information from receptors passes along cells (neurones) as electrical impulses to the central nervous system (CNS). The CNS is the brain and spinal cord. The CNS coordinates the response of effectors which may be muscles contracting or glands secreting hormones.

Stimulus → receptor → coordinator → effector → response

The various structures in a reflex arc – including the sensory neurone, synapse, relay neurone and motor neurone – relate to their function.
Reflex actions are important. Reflex actions are automatic and rapid; they do not involve the conscious part of the brain.
The data from graphs, charts and tables can be extracted to make interpretations about the functioning of the nervous system.

**The brain (biology only)**

The brain controls complex behaviour. It is made of billions of interconnected neurones and has different regions that carry out different functions.
The brain is made up of millions of interconnected neurones arranged in different regions to carry out different functions.
**Cerebral cortex:** consciousness, intelligence, memory, language
**Cerebellum:** coordinating muscular activity and balance
**Medulla:** unconscious activities (e.g., gut movements, breathing)
There are difficulties of investigating brain function and treating brain damage and disease.

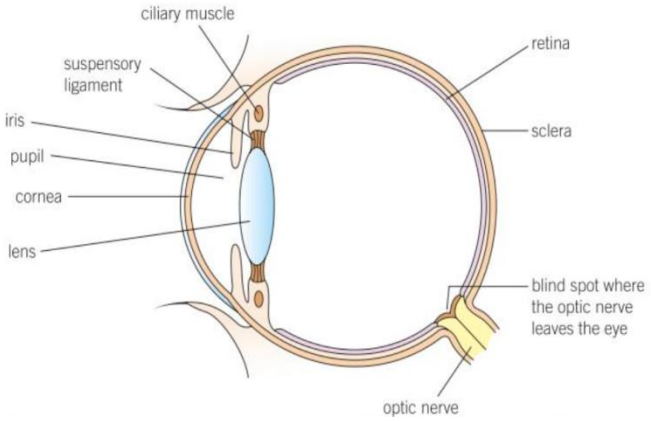


There are many different chemicals released in the synapse (the space between two neurones). It is easily damaged which makes investigating injured brains difficult to treat. Drugs do not always reach the brain through the membranes which surround it. Surgery is too risky and can cause unintended damage. Neuroscientists have been able to map the regions of the brain to particular functions by studying patients with brain damage, electrically stimulating different parts of the brain and using MRI scanning techniques. The complexity and delicacy of the brain makes investigating and treating brain disorders very difficult.
Benefits of using MRI scans: Can produced a detailed image of the brain structure which is affected without turning to invasive surgery.
Disadvantages of using MRI scans: Frequent exposure to radiation can cause cancer. They are also expensive.

**The eye (biology only)**

The eye is a sense organ containing receptors in the retina that are sensitive to light intensity and colour.
Components of the eye are:

**Sclera:** white outer layer of eye, relatively tough and strong so eyeball not easy to damage
**Cornea:** transparent area at front of eyeball that admits light, curved surface to help focus light coming into eye on retina
**Iris:** muscular structure to control size of pupil
**Pupil:** hole in iris through which light enters eye
**Lens**: clear disc to help finely focus light onto retina
**Suspensory ligaments:** attach ciliary muscles to eyeball, involved in changing shape of lens
**Ciliary muscles:** contract and relax to change shape of lens and focus light on retina
**Retina**: layer at back of eye containing light receptor cells
**Optic nerve:** carries impulses from the retina to the brain.
**Blind spot:** where the optic nerve leaves eyeball

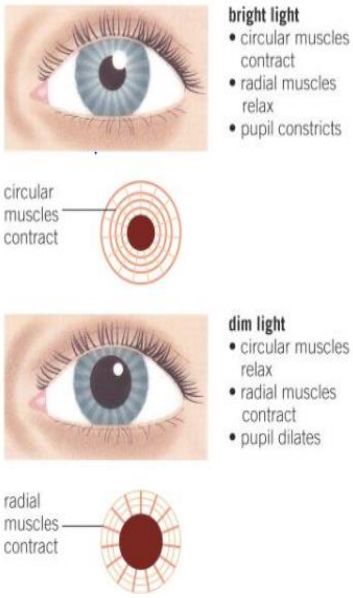



Accommodation is the process of changing the shape of the lens to focus on near or distant objects.
To focus on a near object:

- the ciliary muscles contract
- the suspensory ligaments loosen
- the lens is then thicker and refracts light rays strongly.

To focus on a distant object:

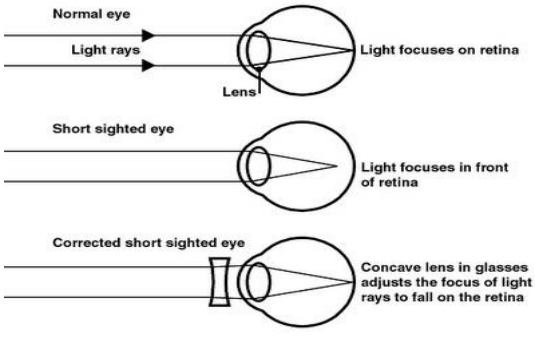
- the ciliary muscles relax
- the suspensory ligaments are pulled tight
- the lens is then pulled thin and only slightly refracts light rays.




Two common defects of the eyes are myopia (short sightedness) and hyperopia (long sightedness) in which rays of light do not focus on the retina.

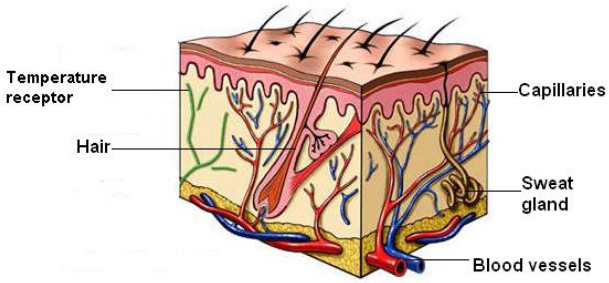
- Generally these defects are treated with spectacle lenses which refract the light rays so that they do focus on the retina.
- New technologies now include hard and soft contact lenses, laser surgery to change the shape of the cornea and a replacement lens in the eye.

Glasses
Advantages: relatively cheap, very effective, don't damage eyes, last a long time
Disadvantages: can be nuisance or get lost, some people don't like look of them
Laser eye surgery
Advantages: only available to adults once eyes have stopped growing and vision has stabilised, vision permanently corrected (nothing to take on and off/in and out), good for playing sport and general activities
Disadvantages: risk of errors and infections during surgery



**Control of body temperature (biology only)**

Body temperature is monitored and controlled by the thermoregulatory centre in the brain. The thermoregulatory centre contains receptors sensitive to the temperature of the blood. The skin contains temperature receptors and sends nervous impulses to the thermoregulatory centre.




If the core body temperature is too high:

- Blood vessels supplying the skin capillaries dilate so that more blood flows through the capillaries and more heat is lost
- Sweat glands release more sweat which cools the body as it evaporates.

If the core body temperature is too low:

- Blood vessels supplying the skin capillaries constrict to reduce the flow of blood through the capillaries
- Muscles may 'shiver' – their contraction needs respiration, which releases some energy to warm the body.

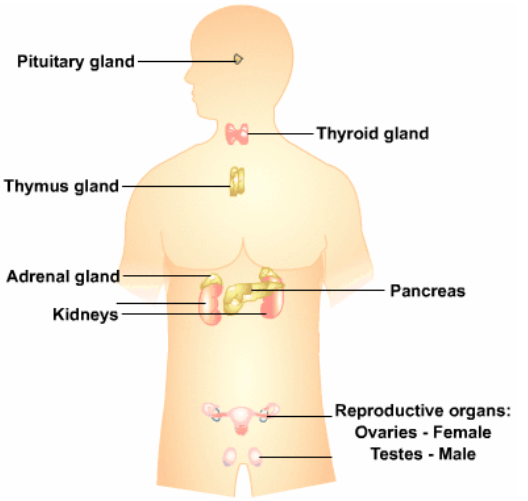
## 4.5.3 Hormonal coordination in humans

**Human endocrine system**

The endocrine system is composed of glands which secrete chemicals called hormones directly into the bloodstream. The blood carries the hormone to a target organ where it produces an effect. Compared to the nervous system the effects are slower but act for longer.

The pituitary gland in the brain is a 'master gland' which secretes several hormones into the blood in response to body conditions. These hormones in turn act on other glands to stimulate other hormones to be released to bring about effects.

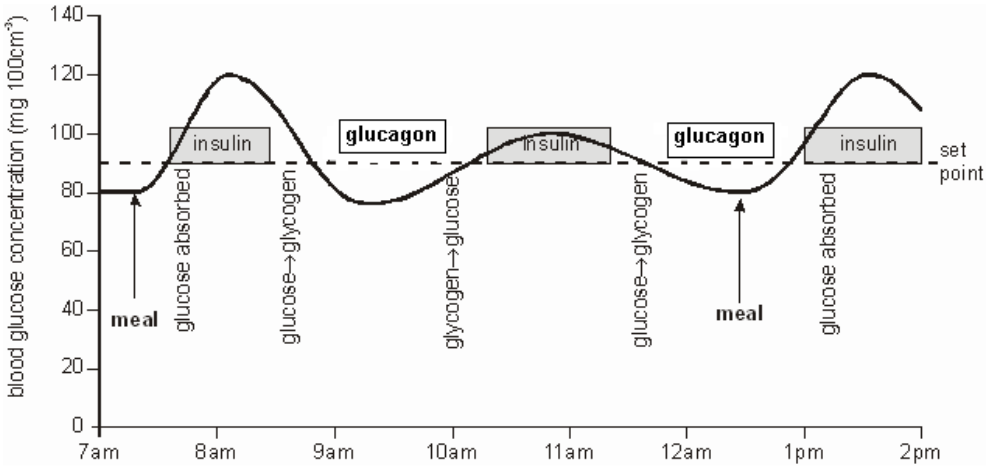
**The endocrine glands and their function**




The **pituitary gland**: lies under the base of the skull.
It secretes eight hormones, some of which are responsible for controlling the other endocrine glands of the body.
The **thyroid gland**: produces thyroxine that controls the speed at which oxygen and food products are burned up to produce energy.
The **pancreas:** secretes digestive juices. It also secretes insulin that regulates the amount of sugar in the blood.
The **ovaries**: in females, secretes oestrogen the hormone that controls the development of secondary sexual characteristics and plays an important part during pregnancy.
The **testes**: in males secretes testosterone the hormone that controls the development of secondary sexual characteristics.
The **adrenal glands**: lie just in front of each kidney. They secrete the hormones adrenalin and noradrenalinat times of stress.

**Control of blood glucose concentration**

Blood glucose concentration is monitored and controlled by the pancreas.
If the blood glucose concentration is too high, the pancreas produces the hormone insulin that causes glucose to move from the blood into the cells. In liver and muscle cells excess glucose is converted to glycogen for storage.
Type 1 diabetes is a disorder in which the pancreas fails to produce sufficient insulin. It is characterised by uncontrolled high blood glucose levels and is normally treated with insulin injections.
In Type 2 diabetes the body cells no longer respond to insulin produced by the pancreas. A carbohydrate controlled diet and an exercise regime are common treatments. Obesity is a risk factor for Type 2 diabetes.
If the blood glucose concentration is too low, the pancreas produces the hormone glucagon that causes glycogen to be converted into glucose and released into the blood.
The glucagon interacts with insulin in a negative feedback cycle to control blood glucose (sugar) levels in the body.



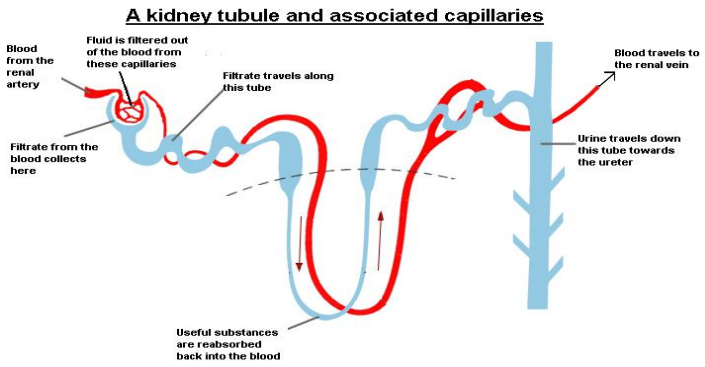

- Insulin from pigs and cows was used to treat diabetic people for many years.
- Insulin is now produced using microorganisms that have been genetically engineered to contain the human insulin gene.
    - This modern insulin is chemically identical to human insulin.
- Pancreas transplants can also be used to treat diabetes in some people.
    - However, there are not enough dead donors to supply all the people who need them.
    - Also, organ transplants are not always successful.
- In the future, stem cells may be used to cure diabetes.
    - However, this requires the use of human embryos, which many people disagree with.

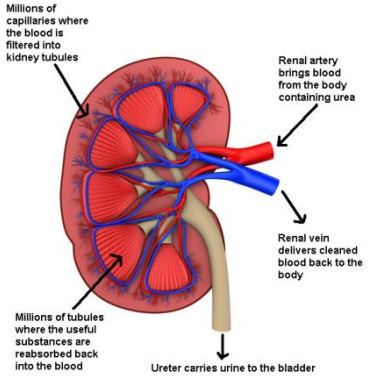
**<u>Maintaining water and nitrogen balance in the body (biology only)</u>**

Cells are effected by osmotic changes in body fluids.
Water leaves the body via the lungs during exhalation. Water, ions and urea are lost from the skin in sweat.
There is no control over water, ion or urea loss by the lungs or skin.
Excess water, ions and urea are removed via the kidneys in the urine.
If body cells lose or gain too much water by osmosis they do not function efficiently.
The digestion of proteins from the diet results in excess amino acids which need to be excreted safely. In the liver these amino acids are deaminated to form ammonia. Ammonia is toxic and so it is immediately converted to urea for safe excretion.
The kidneys are important structures in maintaining the water balance of the body.
The ADH effects on the permeability of the kidney tubules.
The water level in the body is controlled by the hormone ADH which acts on the kidney tubules. ADH is released by the pituitary gland when the blood is too concentrated and it causes more water to be reabsorbed back into the blood from the kidney tubules. This is controlled by negative feedback.
People who suffer from kidney failure may be treated by organ transplant or by using kidney dialysis.
A healthy kidney produces urine by:

- first filtering the blood
- reabsorbing all the sugar
- reabsorbing the dissolved ions needed by the body
- reabsorbing as much water as the body needs
- releasing urea, excess ions and water as urine.

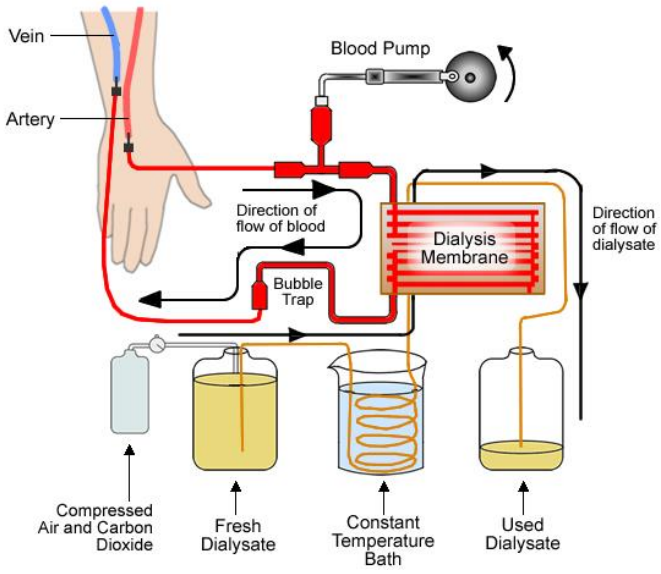
People who suffer from kidney failure may be treated either by using a kidney dialysis machine or by having a healthy kidney transplanted.



Treatment by dialysis restores the concentrations of dissolved substances in the blood to normal level and has to be carried out at regular intervals.

In a dialysis machine a person's blood flows between partially permeable membranes. The dialysis fluid contains the same concentration of useful substances as the blood. This ensures that glucose and useful mineral ions are not lost. Urea passes out from the blood into the dialysis fluid.




In kidney transplants a diseased kidney is replaced with a healthy one from a donor. However, the donor kidney may be rejected by the immune system unless precautions are taken.

Antigens are proteins on the surface of cells. The recipient's antibodies may attack the antigens on the donor organ as they do not recognise them as part of the recipient's body.

To prevent rejection of the transplanted kidney:

- a donor kidney with a 'tissue-type' similar to that of the recipient is used
- the recipient is treated with drugs that suppress the immune system

| | Advantages | Disadvantages |
|---|---|---|
| Dialysis | • No major surgery needed.<br>• No waiting lists – it prevents people dying. | • Diet needs to be controlled carefully.<br>• Restricts normal life – it takes about 8 hours, several times a week. |
| Kidney transplant | • No need for dialysis.<br>• The recipient can lead a relatively normal life.<br>• Diet does not need to be controlled. | • Major surgery has many risks.<br>• Possibility of rejection.<br>• Immunosuppresant drugs need to be taken for life.<br>• Some religious groups do not agree with organ donation. |

## Hormones in human reproduction

During puberty reproductive hormones cause secondary sex characteristics to develop.

Oestrogen is the main female reproductive hormone produced in the ovary. At puberty eggs begin to mature and one is released approximately every 28 days. This is called ovulation.

Testosterone is the main male reproductive hormone produced by the testes and it stimulates sperm production.

Several hormones are involved in the menstrual cycle of a woman.

- Follicle stimulating hormone (FSH) causes maturation of an egg in the ovary.
- Luteinising hormone (LH) stimulates the release of the egg.
- Oestrogen and progesterone are involved in maintaining the uterus lining.

## Contraception

Fertility can be controlled by a variety of hormonal and non-hormonal methods of contraception.

These include:

- oral contraceptives that contain hormones to inhibit FSH production so that no eggs mature
- injection, implant or skin patch of slow release progesterone to inhibit the maturation and release of eggs for a number of months or years
- barrier methods such as condoms and diaphragms which prevent the sperm reaching an egg
- intrauterine devices which prevent the implantation of an embryo or release a hormone
- spermicidal agents which kill or disable sperm
- abstaining from intercourse when an egg may be in the oviduct
- surgical methods of male and female sterilisation.

**The use of hormones to treat infertility (HT only)**

This includes giving FSH and LH in a 'fertility drug' to a woman. She may then become pregnant in the normal way.

In Vitro Fertilisation (IVF) treatment:

- IVF involves giving a mother FSH and LH to stimulate the maturation of several eggs.
- The eggs are collected from the mother and fertilised by sperm from the father in the laboratory.
- The fertilised eggs develop into embryos.
- At the stage when they are tiny balls of cells, one or two embryos are inserted into the mother's uterus (womb).

Although fertility treatment gives a woman the chance to have a baby of her own:

- it is very emotionally and physically stressful
- the success rates are not high
- it can lead to multiple births which are a risk to both the babies and the mother.

**Negative feedback (HT only)**

Thyroxine and adrenaline play important roles in the body.

Adrenaline is produced by the adrenal glands in times of fear or stress. It increases the heart rate and boosts the delivery of oxygen and glucose to the brain and muscles, preparing the body for 'flight or fight'.

Thyroxine from the thyroid gland stimulates the basal metabolic rate. It plays an important role in growth and development. Thyroxine levels are controlled by negative feedback.

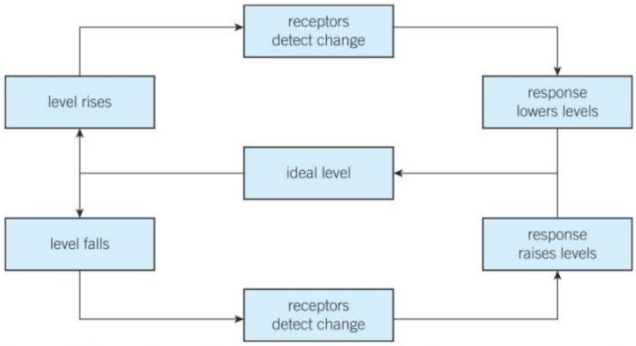



**Figure 1** *A negative feedback loop means values will vary around a normal level within a limited range*

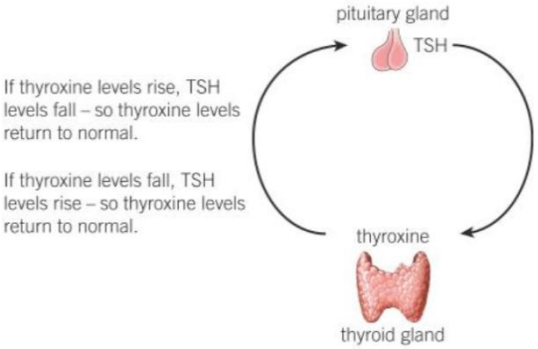



**Figure 2** *The levels of thyroxine in your body are kept within narrow boundaries by a negative feedback loop*

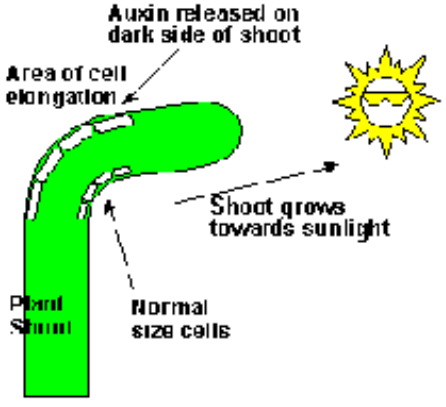
## 4.5.4 Plant hormones (biology only)

**Control and coordination**

Plants produce hormones to coordinate and control growth and responses to light (phototropism) and gravity (gravitropism or geotropism). Unequal distributions of auxin cause unequal growth rates in plant roots and shoots.

Gibberellins are important in initiating seed germination.

Ethene controls cell division and ripening of fruits.




**Use of plant hormones (HT only)**

Plant growth hormones are used in agriculture and horticulture.

Auxins are used:

- as weed killers
- as rooting powders
- for promoting growth in tissue culture.

Ethene is used in the food industry to control ripening of fruit during storage and transport.

Gibberellins can be used to:

- end seed dormancy
- promote flowering
- increase fruit size

# 4.6 Inheritance, variation and evolution

The number of chromosomes are halved during meiosis and then combined with new genes from the sexual partner to produce unique offspring. Gene mutations occur continuously and on rare occasions can affect the functioning of the animal or plant. These mutations may be damaging and lead to a number of genetic disorders or death. Very rarely a new mutation can be beneficial and consequently, lead to increased fitness in the individual. Variation generated by mutations and sexual reproduction is the basis for natural selection; this is how species evolve.

An understanding of these processes has allowed scientists to intervene through selective breeding to produce livestock with favoured characteristics. Once new varieties of plants or animals have been produced it is possible to clone individuals to produce larger numbers of identical individuals all carrying the favourable characteristic.

Scientists have now discovered how to take genes from one species and introduce them in to the genome of another by a process called genetic engineering. In spite of the huge potential benefits that this technology can offer, genetic modification still remains highly controversial.

## 4.6.1 Reproduction

### Sexual and asexual reproduction

Meiosis leads to non-identical cells being formed while mitosis leads to identical cells being formed.

Sexual reproduction involves the joining (fusion) of male and female gametes:

- sperm and egg cells in animals
- pollen and egg cells in flowering plants

In sexual reproduction there is mixing of genetic information which leads to variety in the offspring. The formation of gametes involves meiosis.

Asexual reproduction involves only one parent and no fusion of gametes. There is no mixing of genetic information. This leads to genetically identical offspring (clones). Only mitosis is involved.

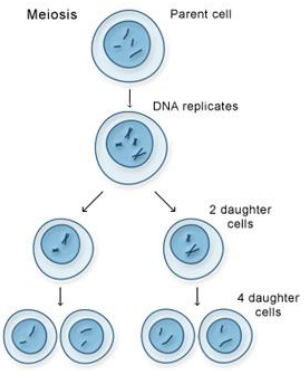
### Meiosis

Meiosis halves the number of chromosomes in gametes and fertilisation restores the full number of chromosomes.

Cells in reproductive organs divide by meiosis to form gametes.

When a cell divides to form gametes:

- copies of the genetic information are made
- the cell divides twice to form four gametes, each with a single set of chromosomes
- all gametes are genetically different from each other.




Gametes join at fertilisation to restore the normal number of chromosomes. The new cell divides by mitosis. The number of cells increases. As the embryo develops cells differentiate.

### Advantages and disadvantages of sexual and asexual reproduction (biology only)

Advantages of sexual reproduction:

- produces variation in the offspring
- if the environment changes variation gives a survival advantage by natural selection
- natural selection can be speeded up by humans in selective breeding to increase food production.

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.

Some organisms reproduce by both methods depending on the circumstances.

- Malarial parasites reproduce asexually in the human host, but sexually in the mosquito.
- Many fungi reproduce asexually by spores but also reproduce sexually to give variation.
- Many plants produce seeds sexually, but also reproduce asexually by runners such as strawberry plants, or bulb division such as daffodils.

## DNA and the genome

The genetic material in the nucleus of a cell is composed of a chemical called DNA. DNA is a polymer made up of two strands forming a double helix. The DNA is contained in structures called chromosomes.
A gene is a small section of DNA on a chromosome. Each gene codes for a particular sequence of amino acids, to make a specific protein.
The genome of an organism is the entire genetic material of that organism. The whole human genome has now been studied and this will have great importance for medicine in the future.

The human genome is important for:

- search for genes linked to different types of disease
- understanding and treatment of inherited disorders
- use in tracing human migration patterns from the past.

## DNA structure (biology only)

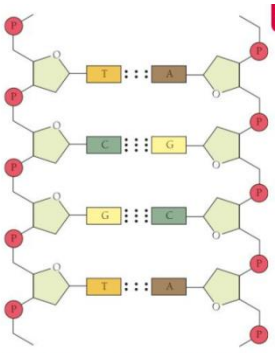


**Figure 2** *The way the bases bind is vital to the structure of the DNA and the way it works*

DNA is a polymer made from four different nucleotides. Each nucleotide consists of a common sugar and phosphate group with one of four different bases attached to the sugar. DNA contains four bases, A, C, G and T. In the complementary strands a C is always linked to a G on the opposite strand and a T to an A. A sequence of three bases is the code for a particular amino acid. The order of bases controls the order in which amino acids are assembled to produce a particular protein.
The long strands of DNA consist 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.
The structure of DNA affects the protein made.

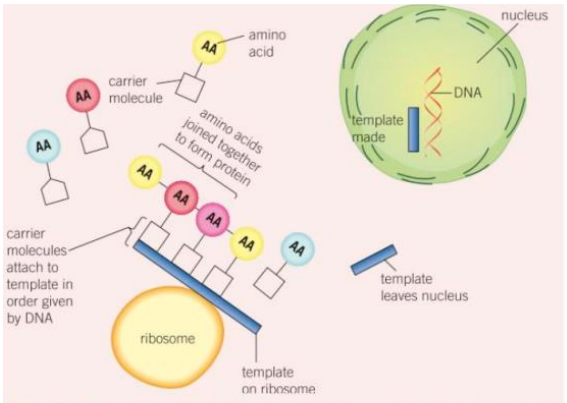



**Figure 3** *Protein synthesis takes place on the ribosomes in the cytoplasm of the cell but is controlled by the sequence of bases on the DNA in the nucleus*

The genetic variants may influence phenotype: a) in coding DNA by altering the activity of a protein: and b) in non-coding DNA by altering how genes are expressed.
The change in DNA structure may result in a change in the protein synthesised by a gene.
Proteins are synthesised on ribosomes, according to a template. Carrier molecules bring specific amino acids to add to the growing protein chain in the correct order.
When the protein chain is complete it folds up to form a unique shape. This unique shape enables the proteins to do their job as enzymes, hormones or forming structures in the body such as collagen.
Mutations occur continuously. Most do not alter the protein, or only alter it slightly so that its appearance or function is not changed. A few mutations code for an altered protein with a different shape. An enzyme may no longer fit the substrate binding site or a structural protein may lose its strength.

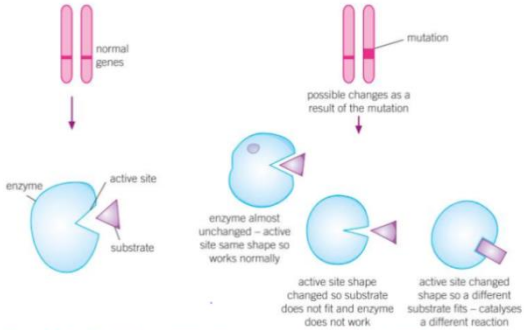



**Figure 3** *The effects of a mutation in a gene range from nothing at all, to a catastrophic failure to produce a vital enzyme, to an improvement in the activity of the enzymes made*

Not all parts of DNA code for proteins. Non-coding parts of DNA can switch genes on and off, so variations in these areas of DNA may affect how genes are expressed.

## Genetic inheritance

An **allele** is a variation of a gene.
**Genotype** is the genetic make-up of organisms which determines one's physical characteristic (phenotype).
**Phenotype** is the physical characteristic observed in an organism, for example, black fur or brown eyes.
A **dominant allele** is always expressed in the phenotype, even if only one copy is present (for example, Cc or CC).
A **recessive allele** is only expressed if two copes are present, for example cc.
**Homozygous**: both alleles for particular characteristic are the same.
**Heterozygous**: individual has two different alleles for particular characteristic.
Some characteristics are controlled by a single gene, such as: fur colour in mice; and red-green colour blindness in humans. Each gene may have different forms called alleles.

The alleles present, or genotype, operate at a molecular level to develop characteristics that can be expressed as a phenotype.
A dominant allele is always expressed, even if only one copy is present.
A recessive allele is only expressed if two copies are present (therefore no dominant allele present).
If the two alleles present are the same the organism is homozygous for that trait, but if the alleles are different they are heterozygous.

**Eg tongue rolling**

There is a gene that control our ability to roll our tongues.
There are 2 alleles for this gene:
The allele that allows us to roll our tongues is dominant (R)
The allele that prevents tongue rolling is recessive (r)

Possible parent combination 1:

Parents' phenotypes: tongue roller X non-tongue roller

Parents' genotypes: RR X rr

Possible alleles in gametes: R and R X r and r

At fertilisation, possible offspring genotypes:

| | R | R |
|---|---|---|
| r | Rr | Rr |
| r | Rr | Rr |

(This is called a Punnett square)

Offspring phenotypes: All tongue rollers (that carry the non-tongue rolling allele).

Possible parent combination 2:

Parents' phenotypes: tongue roller X tongue roller
(both carrying the non-tongue rolling allele)

Parents' genotypes: Rr X Rr

Possible alleles in gametes: R and r X R and r

At fertilisation, possible offspring genotypes:

| | R | r |
|---|---|---|
| R | RR | Rr |
| r | Rr | rr |

Offspring phenotypes: 3 tongue rollers : 1 non-tongue roller

**Inherited disorders**

Some disorders are inherited.

Polydactyl – having extra fingers or toes – is caused by a dominant allele of a gene and can therefore be passed on by only one parent who has the disorder.

Cystic fibrosis (a disorder of cell membranes) must be inherited from both parents. The parents may be carriers of the disorder without actually having the disorder themselves. It is caused by a recessive allele of a gene and can therefore be passed on by parents, neither of whom has the disorder.

**Embryo screening**

People in families that have had certain genetic disorders can have a genetic test to see if they carry the allele for the disease. If they do carry the allele, their embryos can be screened to see if it is affected. They can then decide whether to have an abortion.

This is very controversial. Also, many people are concerned about this because in the future it may enable people to choose other characteristics in their children.

**Sex determination**

Ordinary human body cells contain 23 pairs of chromosomes.

22 pairs control characteristics only, but one of the pairs carries the genes that determine sex.

- In females the sex chromosomes are the same (XX).
- In males the chromosomes are different (XY).

Parents' sex: male X female

Parents sex chromosomes: XY X XX

Possible chromosomes in gametes: X and Y X X and X

At fertilisation:

| | X | Y |
|---|---|---|
| X | XX | XY |
| X | XX | XY |

## 4.6.2 Variation and evolution

**Variation**

The genome and its interaction with the environment influence the development of the phenotype of an organism.

Differences in the characteristics of individuals in a population are called variation and may be due to differences in:

- the genes they have inherited (genetic causes)
- the conditions in which they have developed (environmental causes)
- a combination of genes and the environment

It is important to note:

- That there is usually extensive genetic variation within a population of a species
- That all variants arise from mutations and that: most have no effect on the phenotype; some influence phenotype; very few determine phenotype.

Mutations occur continuously. Very rarely a mutation will lead to a new phenotype. If the new phenotype is suited to an environmental change it can lead to a relatively rapid change in the species.

**Evolution**

Evolution is described as a change in the inherited characteristics of a population over time through a process of natural selection which may result in the formation of a new species.

The theory of evolution by natural selection states that all species of living things have evolved from simple life forms that first developed more than three billion years ago. Evolution occurs through natural selection of variants that give rise to phenotypes best suited to their environment.

If two populations of one species become so different in phenotype that they can no longer interbreed to produce fertile offspring they have formed two new species.

**Selective breeding**

There is a huge impact of selective breeding of food plants and domesticated animals.
Selective breeding (artificial selection) is the process by which humans breed plants and animals for have been doing this for thousands of years since they first bred food crops from wild plants and domesticated animals.
Selective breeding involves choosing parents with the desired characteristic from a mixed population. They are bred together. From the offspring those with the desired characteristic are bred together. This continues over many generations until all the offspring show the desired characteristic.
The characteristic can be chosen for usefulness or appearance:

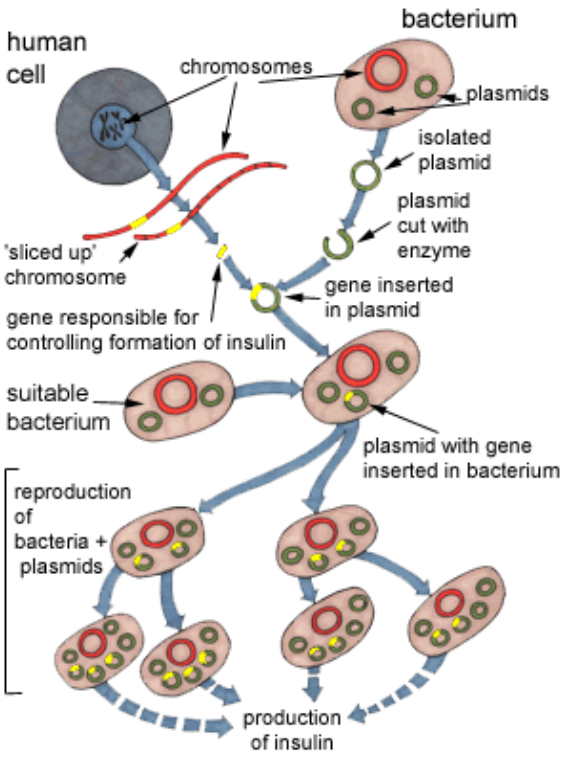
- Disease resistance in food crops.
- Animals which produce more meat or milk.
- Domestic dogs with a gentle nature.
- Large or unusual flowers.

Selective breeding can lead to 'inbreeding' where some breeds are particularly prone to disease or inherited defects.

**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 to produce bigger better fruits.
Bacterial cells have been genetically engineered to produce useful substances such as human insulin to treat diabetes. There are potential benefits and risks of genetic engineering in agriculture and in medicine and that some people have objections. In genetic engineering, genes from the chromosomes of humans and other organisms can be 'cut out' and transferred to cells of other organisms.
Crops that have had their genes modified in this way are called genetically modified (GM) crops. GM crops include ones that are resistant to insect attack or to herbicides. GM crops generally show increased yields.
Concerns about GM crops include the effect on populations of wild flowers and insects. Some people feel the effects of eating GM crops on human health have not been fully explored.
Modern medical research is exploring the possibility of genetic modification to overcome some inherited disorders.
The main steps in the process of genetic engineering are:

- enzymes are used to isolate the required gene; this gene is inserted into a vector, usually a bacterial plasmid or a virus
- the vector is used to insert the gene into the required cells
- genes are transferred to the cells of animals, plants or microorganisms at an early stage in their development so that they develop with desired characteristics.

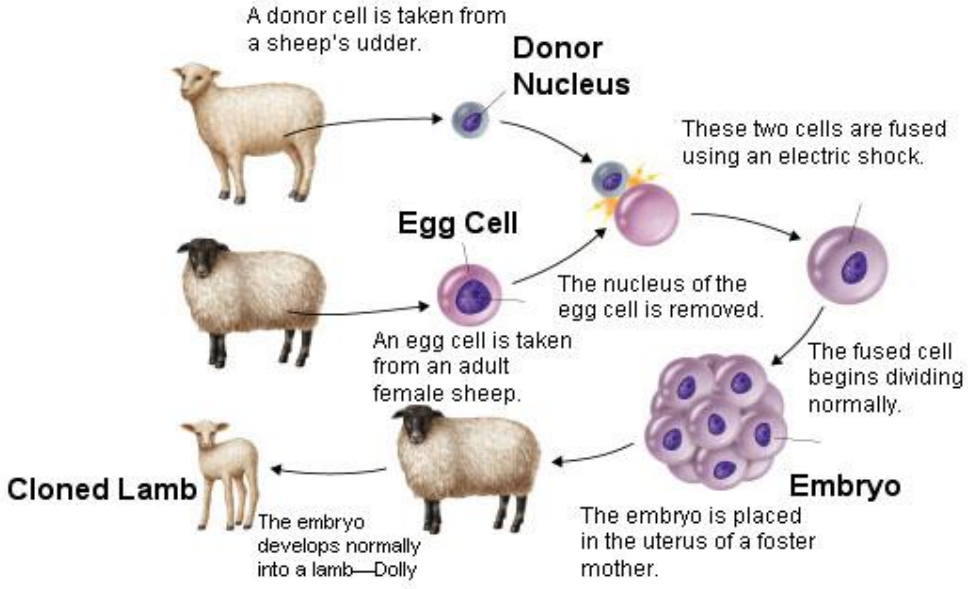



**Cloning (biology only)**

Modern cloning techniques include:
Tissue culture: using small groups of cells from part of a plant to grow identical new plants. This is important for preserving rare plant species or commercially in nurseries.
Cuttings: an older, but simple, method used by gardeners to produce many identical new plants from a parent plant.
Embryo transplants: splitting apart cells from a developing animal embryo before they become specialised, then transplanting the identical embryos into host mothers.

Adult cell cloning:

- The nucleus is removed from an unfertilised egg cell.
- The nucleus from an adult body cell, such as a skin cell, is inserted into the egg cell.
- An electric shock stimulates the egg cell to divide to form an embryo.
- These embryo cells contain the same genetic information as the adult skin cell.
- When the embryo has developed into a ball of cells, it is inserted into the womb of an adult female to continue its development.




## 4.6.3 The development of understanding of genetics and evolution

**Theory of evolution (biology only)**

Charles Darwin, as a result of observations on a round the world expedition, backed by years of experimentation and discussion and linked to developing knowledge of geology and fossils, proposed the theory of evolution by natural selection.

- 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.

Darwin published his ideas in On the Origin of Species (1859). There was much controversy surrounding these revolutionary new ideas.

The 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 was published.

Other theories, including that of Jean-Baptiste Lamarck, are based mainly on the idea that changes that occur in an organism during its lifetime can be inherited. We now know that in the vast majority of cases this type of inheritance cannot occur.

**Speciation (biology only)**

Alfred Russel Wallace independently proposed the theory of evolution by natural selection. He published joint writings with Darwin in 1858 which prompted Darwin to publish On the Origin of Species (1859) the following year.

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.

Alfred Wallace did much pioneering work on speciation but more evidence over time has led to our current understanding of the theory of speciation.

New species arise as a result of:

- Isolation – two populations of a species become separated, eg geographically
- Genetic variation – each population has a wide range of alleles that control their characteristics
- Natural selection – in each population, the alleles that control the characteristics which help the organism to survive are selected
- Speciation – the populations become so different that successful interbreeding is no longer possible.

**The understanding of genetics (biology only)**

The development of our understanding of genetics is due to the work of Mendel
The importance of Mendel's discovery was not recognised until after his death.
In the mid-19th century Gregor Mendel carried out breeding experiments on plants. One of his observations was that the inheritance of each characteristic is determined by 'units' that are passed on to descendants unchanged. In the late 19th century behaviour of chromosomes during cell division was observed.
In the early 20th century it was observed that chromosomes and Mendel's 'units' behaved in similar ways. This led to the idea that the 'units', now called genes, were located on chromosomes.
In the mid-20th century the structure of DNA was determined and the mechanism of gene function worked out. This scientific work by many scientists led to the gene theory being developed.

**Evidence for evolution**

Evidence for evolution includes fossils and antibiotic resistance in bacteria. 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. There is further evidence in the fossil record and the knowledge of how resistance to antibiotics evolves in bacteria.

**Figure 1** *This baby mammoth was preserved in ice for at least 10 000 years. Examining this kind of evidence helps scientists to check the accuracy of ideas, based on fossil skeletons alone*

**Fossils**

Fossils are the 'remains' of organisms from millions of years ago, which are found in rocks. Fossils may be formed:

- from parts of organisms that have not decayed because one or more of the conditions needed for decay are absent
- when parts of the organism are replaced by minerals as they decay
- as preserved traces of organisms, such as footprints, burrows and rootlet traces.

Many early forms of life were soft-bodied, which means that they have left few traces behind. What traces there were have been mainly destroyed by geological activity. This is why scientists cannot be certain about how life began on Earth. We can learn from fossils how much or how little different organisms have changed as life developed on Earth.

**Extinction**

Extinctions occur when there are no remaining individuals of a species still alive.
Extinction may be caused by:

- Changes to the environment over geological time
- New predators
- New diseases
- New, more successful, competitors
- A single catastrophic event, eg massive volcanic eruptions or collisions with asteroids
- Through the cyclical nature of speciation.

**Resistant bacteria**

Bacteria can evolve rapidly because they reproduce at a fast rate.
Mutations of bacterial pathogens produce new strains. Some strains might be resistant to antibiotics, and so are not killed. They survive and reproduce, so the population of the resistant strain rises. The resistant strain will then spread because people are not immune to it and there is no effective treatment. MRSA is resistant to antibiotics.
To reduce the rate of development of antibiotic resistant strains:

- doctors should not prescribe antibiotics inappropriately, such as treating non-serious or viral infections
- patients should complete their course of antibiotics so all bacteria are killed and none survive to mutate and form resistant strains
- the agricultural use of antibiotics should be restricted

The development of new antibiotics is costly and slow. It is unlikely to keep up with the emergence of new resistant strains.

## 4.6.4 Classification of living organisms

Traditionally living things have been classified into groups depending on their structure and characteristics in a system developed by Carl Linnaeus. Linnaeus classified living things into kingdom, phylum, class, order, family, genus and species. Organisms are named by the binomial system of genus and species.

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.

Due to evidence available from chemical analysis there is now a 'three domain system' developed by Carl Woese. In this system organisms are divided into:

- archaea (primitive bacteria usually living in extreme environments)
- bacteria (true bacteria)
- eukaryota (which includes protists, fungi, plants and animals)

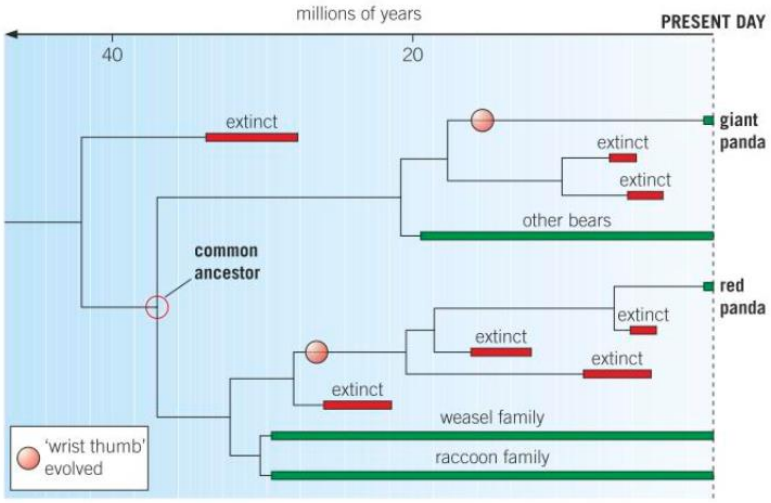



**Figure 2** *Evolutionary trees such as this show us the best model of the evolutionary relationships between organisms*

Evolutionary trees are a method used by scientists to show how they believe organisms are related. They use current classification data for living organisms and fossil data for extinct organisms

# 4.7 Ecology

The Sun is a source of energy that passes through ecosystems. Materials including carbon and water are continually recycled by the living world, being released through respiration of animals, plants and decomposing microorganisms and taken up by plants in photosynthesis.

All species live in ecosystems composed of complex communities of animals and plants dependent on each other and that are adapted to particular conditions, both abiotic and biotic. These ecosystems provide essential services that support human life and continued development.

In order to continue to benefit from these services humans need to engage with the environment in a sustainable way. Humans are threatening biodiversity as well as the natural systems that support it. Actions need to be taken to ensure our future health, prosperity and well-being.

## 4.7.1 Adaptations, interdependence and competition

### Communities

**A community** includes all populations of interdependent different species living in a habitat. Organisms are adapted to the conditions in which they live.

Within a community, each species depends on other species for:

1. Food
2. Shelter
3. Pollination
4. Predation
5. Building nests and shelters
6. Nutrient recycling

**An ecosystem** is made up of communities of organisms in a habitat and their interactions with abiotic (non-living) elements of habitat.

To survive and reproduce, organisms require a supply of materials from their surroundings and from the other living organisms there. Plants in a community or habitat often compete with each other for light and space, and for water and mineral ions from the soil. Animals often compete with each other for food, mates and territory.

If one species is removed it can affect the whole community. This is called interdependence. A stable community is one where all the species and environmental factors are in balance so that population sizes remain fairly constant.

**Abiotic factors**

The change in an abiotic factor would affect a given community. Abiotic (non-living) factors which can affect a community are:

- light intensity
- temperature
- moisture levels
- soil pH and mineral content
- wind intensity and direction
- carbon dioxide levels for plants
- oxygen levels for aquatic animals

**Biotic factors**

A change in a biotic factor might affect a given community.
Biotic (living) factors which can affect a community are:

- availability of food
- new predators arriving
- new pathogens
- one species outcompeting another so the numbers are no longer sufficient to breed

**Adaptations**

Organisms are adapted to live in their natural environment. They have features (adaptations) that enable them to survive in the conditions in which they normally live. These adaptations may be structural, behavioural or functional.

Some organisms live in environments that are very extreme, such as at high temperature, pressure, or salt concentration. These organisms are called extremophiles. Bacteria living in deep sea vents are extremophiles.

Animals and plants may be adapted for survival in the conditions where they normally live, eg deserts, the Arctic.

Animals may be adapted for survival in dry and arctic environments by means of:

- Changes to surface area
- Thickness of insulating coat
- Amount of body fat
- Camouflage.

Plants may be adapted to survive in dry environments by means of:

- Changes to surface area, particularly of the leaves
- Water-storage tissues
- Extensive root systems.

Animals and plants may be adapted to cope with specific features of their environment, eg thorns, poisons and warning colours to deter predators.

Camel

- The camel can go without food and water for 3 to 4 days.
- Fat stored in their humps provides long term food reserve, and a supply of metabolic water. The fat is not distributed around the body; this reduces insulation, allowing more heat loss.
- They are tall and thin, increasing their surface area to volume ratio, increasing heat loss by radiation.

Polar Bear

- Polar bear has thick fur and fat beneath its skin to insulate it.
- Their large, furry feet help to distribute their weight as they walk on a thin ice.
- They are white which camouflages them against the snow. This helps them to hunt.
- They are compact in shape, reducing their surface area to volume ratio; this reduces heat loss by radiation.

Desert plants

- Eg the cactus, require very little water to survive
- Leaves are spines. Spines guard against most browsing herbivorous animals.
- Spines also reduce their surface area, reducing water loss by evaporation
- A thick waxy coating surrounds the plant to reduce evaporation.

- Fewer 'stomata', reducing water loss
- Roots tend to spread sideways to catch rain water.

Arctic plants

- Many of the plants are small, growing close to the ground and very close together to avoid the wind and conserve heat.
- Some possess a light, fuzzy covering to insulate the buds so they can grow.
- Many are dark colours of blue and purple to absorb the heat from the sunlight even during the winter months.
- Because of the cold and short growing seasons, arctic plants grow very slowly.
- Some grow for ten years before they produce any buds for reproduction.

## 4.7.2 Organisation of an ecosystem

**Levels of organisation**

Photosynthetic organisms are the producers of biomass for life on Earth.
Feeding relationships within a community can be represented by food chains. All food chains begin with a producer which synthesises molecules. This is usually a green plant or alga which makes glucose by photosynthesis.
A range of experimental methods using transects and quadrats are used by ecologists to determine the distribution and abundance of species in an ecosystem.

Quadrats

These are square frames, used to mark off specific areas of ground. They are typically 0.5m X 0.5m with a grid of 10cm X 10 cm. They can be used to survey: which species are present, numbers of each species, or percentage cover of a species.

Random Sampling:

- Construct a regular grid using tape across the area.
- Generate random numbers using a calculator or computer.
- Use these to determine coordinates.
- This ensures that there is no bias by the investigator.
- It ensures the results are valid.
- Investigate the population of the species in the quadrat.
- Repeat many times.

Transects

- They are used when:
- There are changes in the distribution of a population of an organism.
- There are two neighbouring habitat eg grassland to woodland
- Or, if a particular factor leads to zonation
- Eg the effect of the tide and coverage by water on rocky seashore.

Method

- Choose the start and end positions of the transect
- Determine the direction and length of the transect
- Lay down a tape or string to mark out transect.
- Sample the organisms along the line.
- Perform further parallel transects to ensure results are reliable.
- Take recording of the factors that could be influencing the distribution along the transect

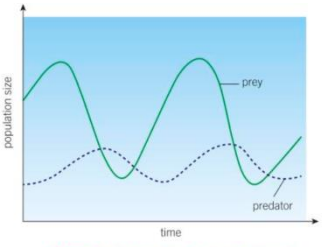
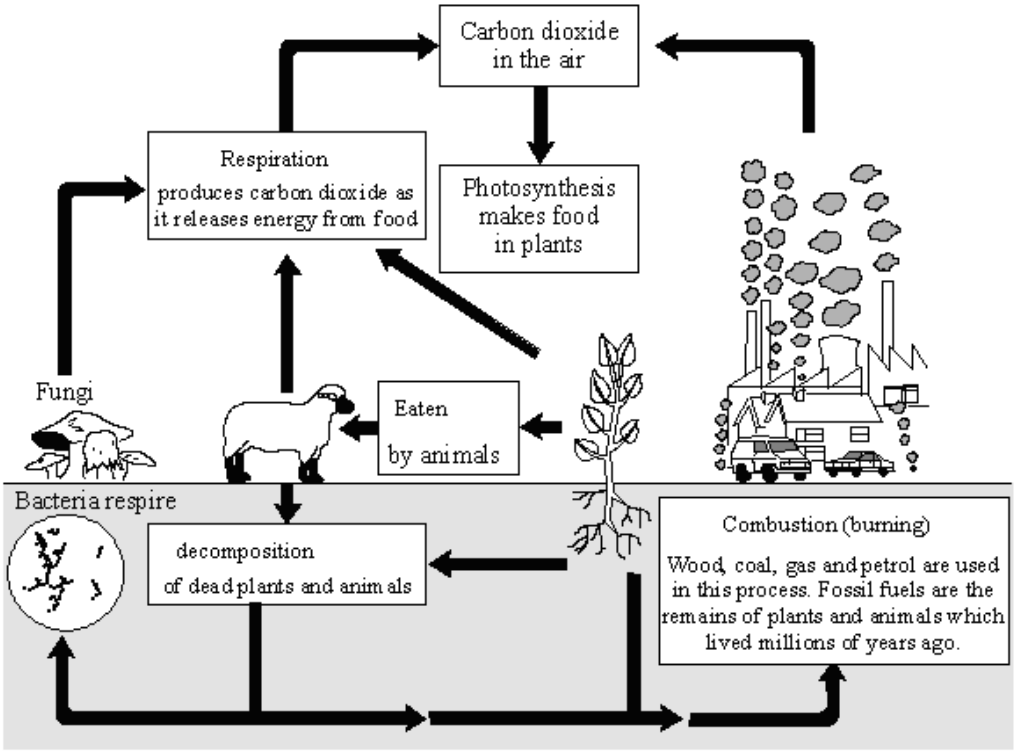



**Figure 2** *The numbers of many different predator–prey populations show typical rises and falls*

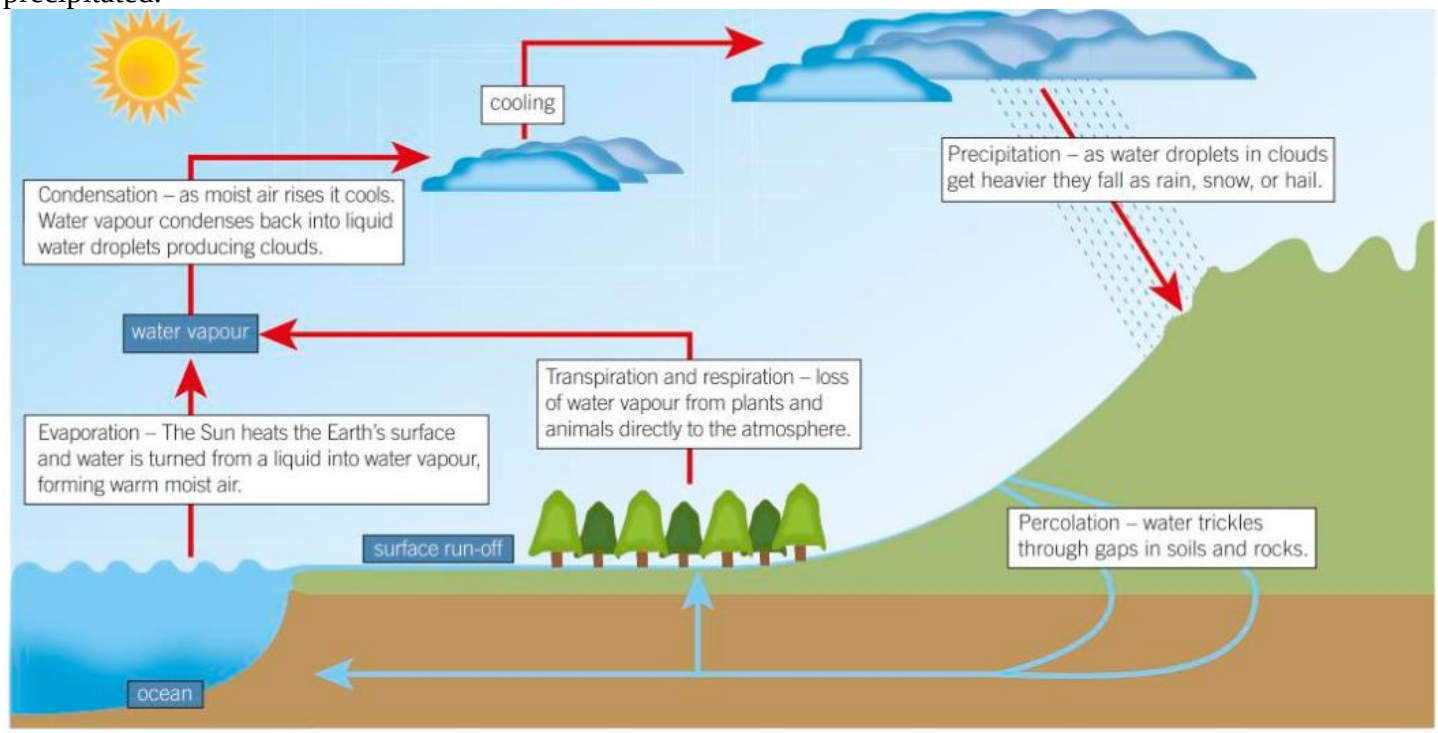
Producers are eaten by primary consumers, which in turn may be eaten by secondary consumers and then tertiary consumers. Consumers that kill and eat other animals are predators, and those eaten are prey. In a stable community the numbers of predators and prey rise and fall in cycles.

## How materials are cycled

Many different materials cycle through the abiotic and biotic components of an ecosystem.
The carbon and water cycles are very important to living organisms.
All materials in the living world are recycled to provide the building blocks for future organisms.
The carbon cycle returns carbon from organisms to the atmosphere as carbon dioxide to be used by plants in photosynthesis.
Microorganisms are involved in cycling materials through an ecosystem by returning carbon to the atmosphere as carbon dioxide and mineral ions to the soil.

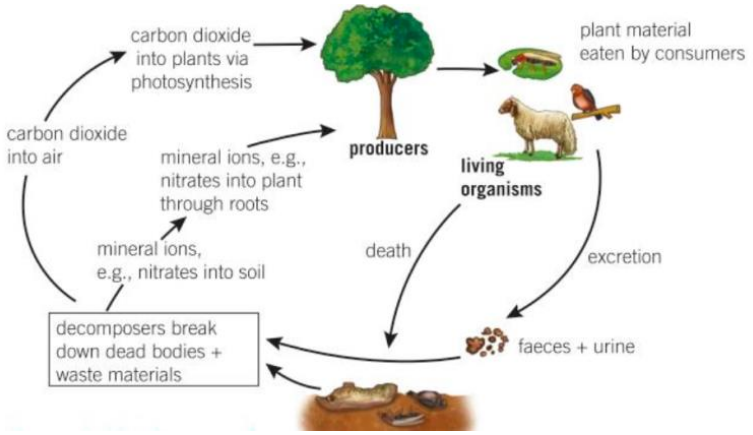



The water cycle provides fresh water for plants and animals on land before draining into the seas. Water is continuously evaporated and precipitated.




## Decomposition (biology only)

Temperature, water and availability of oxygen affect the rate of decay of biological material.
Gardeners and farmers try to provide optimum conditions for rapid decay of waste biological material. The compost produced is used as a natural fertiliser for growing garden plants or crops.
Anaerobic decay produces methane gas. Biogas generators can be used to produce methane gas as a fuel.



**Impact of environmental change (biology only) (HT only)**

The environmental changes have an impact on the distribution of species in an ecosystem. These changes include:

- temperature
- availability of water
- composition of atmospheric gases

The changes may be seasonal, geographic or caused by human interaction.

## 4.7.3 Biodiversity and the effect of human interaction on ecosystems

**Biodiversity**

Biodiversity is the variety of all the different species of organisms on earth, or within an ecosystem.
A great biodiversity ensures the stability of ecosystems by reducing the dependence of one species on another for food, shelter and the maintenance of the physical environment. The future of the human species on Earth relies on us maintaining a good level of biodiversity. Many human activities are reducing biodiversity and only recently have measures been taken to try to stop this reduction.

**Waste management**

Rapid growth in the human population and an increase in the standard
of living mean that increasingly more resources are used and more waste is produced. Unless waste and chemical materials are properly handled, more pollution will be caused.
Pollution can occur:

- in water, from sewage, fertiliser or toxic chemicals
- in air, from smoke and acidic gases
- on land, from landfill and from toxic chemicals.

Pollution kills plants and animals which can reduce biodiversity

**Land use**

Humans reduce the amount of land available for other animals and plants by building, quarrying, farming and dumping waste. The destruction of peat bogs, and other areas of peat to produce garden compost, reduces the area of this habitat and thus the variety of different plant, animal and microorganism species that live there (biodiversity). The decay or burning of the peat releases carbon dioxide into the atmosphere.

**Deforestation**

Large-scale deforestation in tropical areas has occurred to:

- provide land for cattle and rice fields
- grow crops for biofuels

Large-scale deforestation in tropical areas, for timber and to provide land for agriculture, has:

- increased the release of carbon dioxide into the atmosphere (because of burning and the activities of microorganisms)
- reduced the rate at which carbon dioxide is removed from the atmosphere and ‘locked up’ for many years as wood
- reduction in biodiversity

**Air pollution**

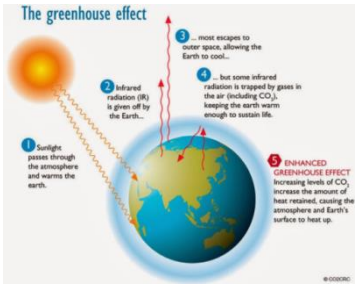
Pollution can occur in the air from smoke and from acidic gases. Acidic gases are released into the atmosphere and spread around by the wind.
Air pollution kills plants and animals, which can reduce biodiversity.

**Acid rain** forms when sulfur dioxide and nitrogen oxides dissolve into rain and snow.

1. Acid rain directly damages plant life by falling on plants and by soaking into soil and being taken up by roots.
2. Acid rain contaminates soil and watercourses, making them more acidic and eventually unable to sustain life. Increasing sulfur dioxide levels threaten to reduce global biodiversity as whole ecosystems can be destroyed.

**Global warming**

Carbon dioxide and methane in the atmosphere absorb most of the energy radiated by the Earth. Some of this energy is reradiated back to the Earth and so keeps the Earth warmer than it would otherwise be.




The greenhouse effect**:** when energy transferred from Sun to Earth. Much of this heat is reflected back into space, but some is absorbed by greenhouse gases in the atmosphere and reradiated back to Earth. Earth's surface and atmosphere are warmed (greenhouse effect), maintaining conditions ideal for life.

The impact of global warming**:**

- loss of habitat – reducing biodiversity
- changes in distribution – some organisms may disappear from some areas as habitat changes
- changes in migration patterns – caused by changes in climates and seasons
- reduced biodiversity – some organisms will become extinct as climate changes

**Maintaining biodiversity**

There are both positive and negative human interactions in an ecosystem and have an impact on biodiversity. Scientists and concerned citizens have put in place programmes to reduce the negative effects of humans on ecosystems and biodiversity.

These include:

- breeding programmes for endangered species
- protection and regeneration of rare habitats
- reintroduction of field margins and hedgerows in agricultural areas where farmers grow only one type of crop
- reduction of deforestation and carbon dioxide emissions by some governments
- recycling resources rather than dumping waste in landfill

## 4.7.4 Trophic levels in an ecosystem (biology only)

**Trophic levels**

Trophic levels can be represented by numbers, starting at level 1 with plants and algae. Further trophic levels are numbered subsequently according to how far the organism is along the food chain.

Level 1: Plants and algae make their own food and are called producers.

Level 2: Herbivores eat plants/algae and are called primary consumers.

Level 3: Carnivores that eat herbivores are called secondary consumers.

Level 4: Carnivores that eat other carnivores are called tertiary consumers. Apex predators are carnivores with no predators.

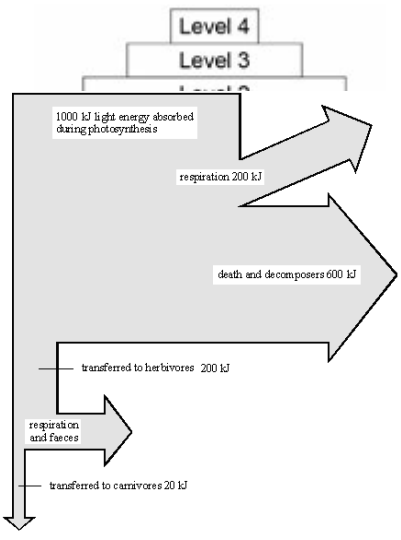
Decomposers break down dead plant and animal matter by secreting enzymes into the environment. Small soluble food molecules then diffuse into the microorganism.

**Pyramids of biomass**

Pyramids of biomass can be constructed to represent the relative amount of biomass in each level of a food chain. Trophic level 1 is at the bottom of the pyramid.

- Biomass = mass of living material

All pyramids of biomass are pyramid shaped. The mass of living material (biomass) at each stage in a food chain is less than it was at the previous stage.




**Transfer of biomass**

Biomass is lost between the different trophic levels.

Producers are mostly plants and algae which transfer about 1 % of the incident energy from light for photosynthesis. Only approximately 10 % of the biomass from each trophic level is transferred to the level above it.

Losses of biomass are due to:

- not all the ingested material is absorbed, some is egested as faeces
- some absorbed material is lost as waste, such as carbon dioxide and water in respiration and water and urea in urine

Large amounts of glucose are used in respiration.

## 4.7.5 Food production (biology only)

**Factors affecting food security**

Food security is having enough food to feed a population.

Biological factors which are threatening food security include:

- the increasing birth rate has threatened food security in some countries
- changing diets in developed countries means scarce food resources are transported around the world
- new pests and pathogens that affect farming
- environmental changes that affect food production, such as widespread famine occurring in some
- countries if rains fail
- the cost of agricultural inputs
- conflicts that have arisen in some parts of the world which affect the availability of water or food

Sustainable methods must be found to feed all people on Earth.

**Farming techniques**

The efficiency of food production can be improved by restricting energy transfer from food animals to the environment. This can be done by limiting their movement and by controlling the temperature of their surroundings. Some animals are fed high protein foods to increase growth.

**Sustainable fisheries**

Fish stocks in the oceans are declining. It is important to maintain fish stocks at a level where breeding continues or certain species may disappear altogether in some areas. Control of net size and the introduction of fishing quotas play important roles in conservation of fish stocks at a sustainable level.

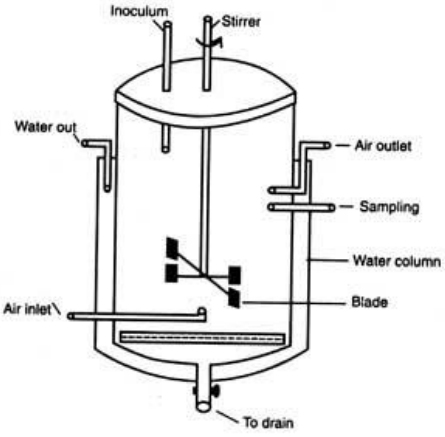
**Role of biotechnology**

Modern biotechnology techniques enable large quantities of microorganisms to be cultured for food.

The fungus Fusarium is useful for producing mycoprotein, a protein-rich food suitable for vegetarians. The fungus is grown on glucose syrup, in aerobic conditions, and the biomass is harvested and purified.

A genetically modified bacterium produces human insulin. When harvested and purified this is used to treat people with diabetes.

The stirrer prevents clogging and the jacked ensure that temperature is maintained. This method of food production may become more important when land availability for farms becomes restrictive. This may not be popular because many people prefer to eat meat.




GM crops could provide more food or food with an improved nutritional value such as golden rice.