Cambridge OL

Biology

CODE: (5090)

Chapter 15 and chapter 16

Coordination and response in plants and Development of organisms and continuity of life

Tropic responses

Sensitivity is the ability of living organisms to respond to stimuli. Although plants do not respond by moving their whole bodies, parts of them do respond to stimuli. Some of these responses are described as tropic responses or tropisms

Key definitions

Gravitropism is a response in which parts of a plant grow towards or away from gravity.

Phototropism is a response in which parts of a plant grow towards or away from light.

Tropisms

Tropisms are growth movements related to directional stimuli. Growth movements of this kind are usually in response to the direction of light or gravity. Responses to light are called phototropisms; responses to gravity are gravitropisms.

If the plant organ responds by growing towards the stimulus, the response is said to be 'positive'. If the response is growth away from the stimulus it is said to be 'negative'.

▲ **Figure 15.1** Negative gravitropism. The tomato plant has been left on its side for 24 hours

Advantages of tropic responses

Positive phototropism of shoots

By growing towards the source of light, a shoot brings its leaves into the best situation for photosynthesis. Similarly, the flowers are brought into an exposed position where they are most likely to be seen and pollinated by flying insects.

Negative gravitropism in shoots

Shoots that are negatively gravitropic grow vertically. This lifts the leaves and flowers above the ground and helps the plant to compete for light and carbon dioxide. The flowers are brought into a beneficial position for insect or wind pollination. Seed dispersal may be more effective from fruits on a long, vertical stem.

Stems that form rhizomes (stems that grow underground) are not negatively gravitropic; they grow horizontally below the ground, though the shoots that grow up from them are negatively gravitropic

Positive gravitropism in roots

By growing towards gravity, roots move deeper into the soil, which is their means of anchorage and their source of water and mineral ions.

Plant growth substances and tropisms

Control of growth

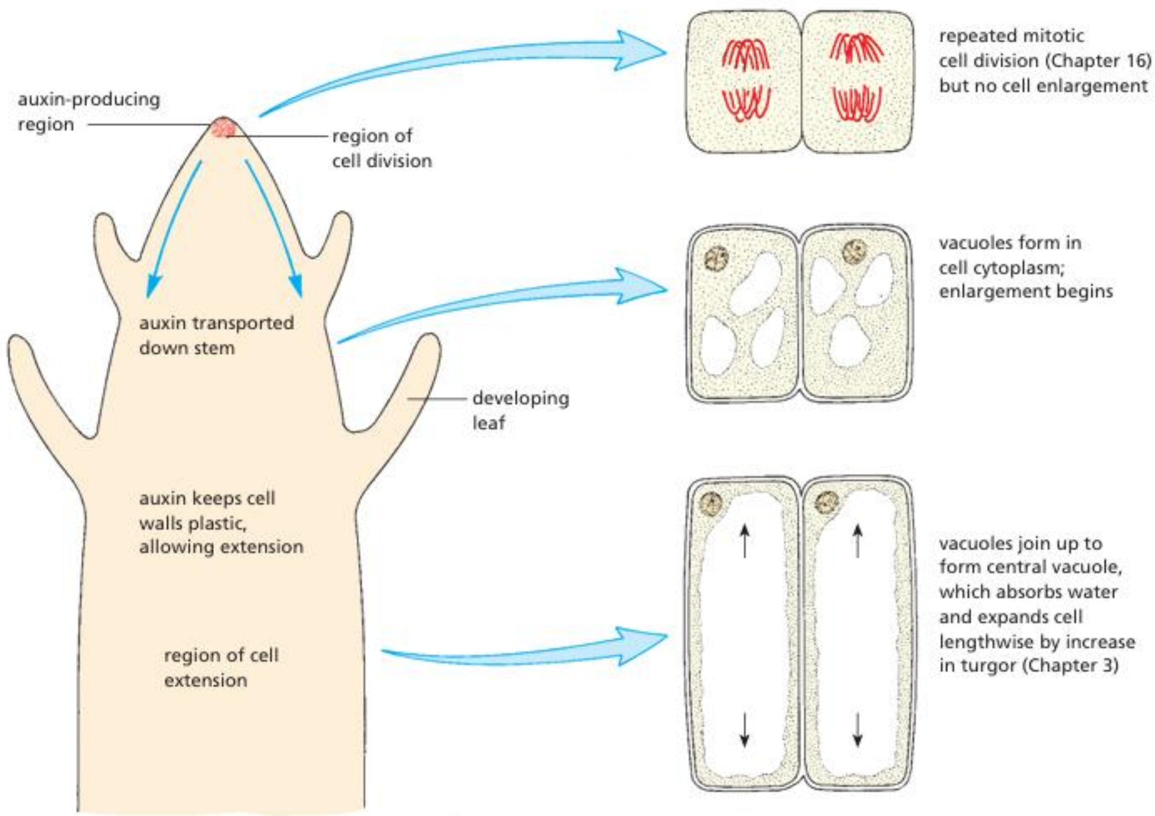
In animals and plants, the growth rate and amount of growth are controlled by chemicals: hormones in animals and growth substances in plants. One of the growth substances is **auxin**.

The responses made by shoots and roots to light and gravity are influenced by growth substances. It has already been explained that growth substances (e.g. auxin) are produced by the tips of roots and shoots and can stimulate or, in some cases, prevent extension growth.

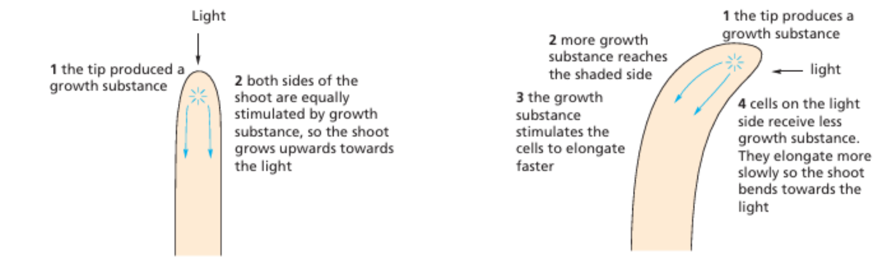
Summary of control of shoot growth by auxin

In the case of phototropism, scientists accept that the distribution of growth substance causes reduced extension on the illuminated side and/or increased extension on the non-illuminated side.

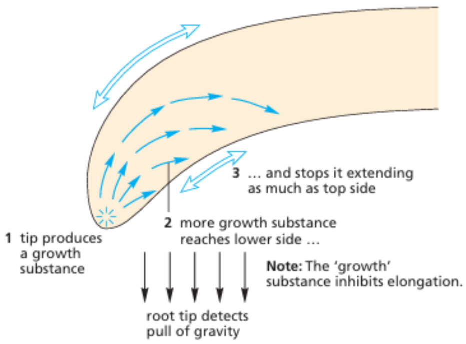
If a shoot is placed horizontally in the absence of light, auxins build up on the lower side of the shoot, due to gravity. This makes the cells on the lower side elongate faster than those on the upper side, so the shoot bends upwards. This is called negative gravitropism.



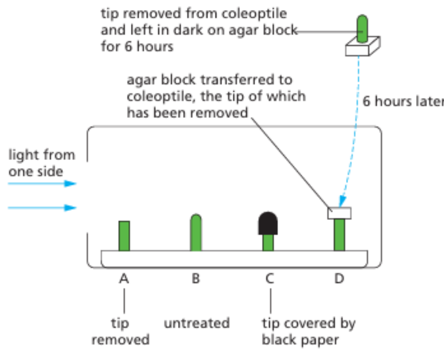
▲ **Figure 15.5** Extension growth at a shoot tip



▲ **Figure 15.6** Possible explanation of positive phototropism in shoots



▲ **Figure 15.7** Possible explanation of positive gravitropism in roots



▲ **Figure 15.8** Investigation into how auxin works

Classic experiments to test how auxins work

Wheat, like grass, belongs to the monocotyledon group of flowering plants. During germination, wheat seeds produce a coleoptile, a protective sheath that protects new leaves from damage. These coleoptiles, which take 2-3 days to grow, are ideal for tropism experiments and can be cut off without harming the plant.

The tip of the coleoptile, where it is expected that auxins would be produced, can be cut off without killing the plant, effectively removing the source of the auxin.

Results

A. No elongation of the coleoptile occurs and there is no bending.
B. The coleoptile grows taller and bends towards the light.
C. The coleoptile grows taller, but there is no bending.
D. The coleoptile grows taller and bends towards the light.

Interpretation

In **A**, the source of auxin has been removed. Auxin is needed to stimulate elongation and stimulates a response to light. It could also be argued that the tip provides cells for growth and this source of cells has been removed.

In **B**, auxin is produced by the tip of the coleoptile. It diffuses down the coleoptile and collects on the shaded side (or is destroyed by the light on the light side). Cells on the shaded side respond to the auxin by elongating faster than on the light side, causing the coleoptile to grow towards the light

In **C**, auxin is produced by the tip and diffuses down, causing all cells on both sides of the coleoptile to elongate at an equal rate, and so causing an increase in length. However, the black paper prevents the light influencing the auxin, so there is no response to the direction of light.

In **D**, auxin is produced by the tip of the coleoptile. It diffuses into the agar block. When the agar block is replaced on the cut coleoptile, the auxin diffuses down from the agar and collects on the shaded side of the coleoptile (or is destroyed by the light on the light side).

Chapter 16 - Development of organisms and continuity of life

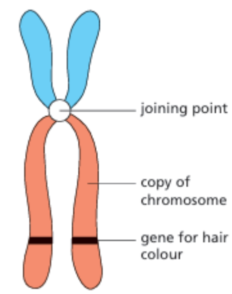
Chromosomes, genes and nuclei

Key definitions

A **haploid nucleus** is a nucleus containing a single set of chromosomes.

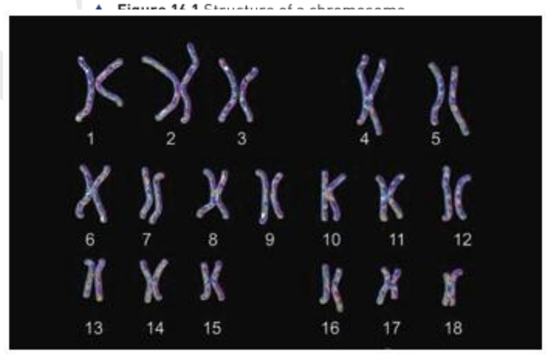
A **diploid nucleus** is a nucleus containing two sets of chromosomes.

A chromosome contains a DNA molecule, which carries genetic information in the form of genes. A gene is a length of DNA that codes for a protein. Inside a nucleus are thread-like structures called chromosomes, which can be seen most clearly when the cell is dividing.



A human body cell nucleus contains 46 chromosomes. These are difficult to distinguish when packed inside the nucleus, so scientists separate them and arrange them according to size and appearance (Figure 16.2). There are pairs of chromosomes

Number of chromosomes



▲ **Figure 16.2** Human chromosomes

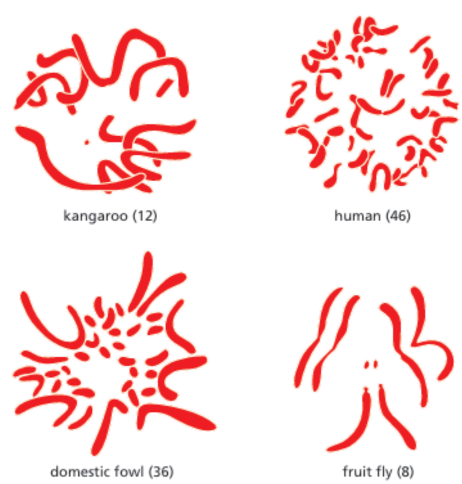
Each species has a fixed number of chromosomes, with human body cells having 46, mouse cells having 40, and garden pea cells having 14. These chromosomes are always in pairs, with 23 from the mother and 23 from the father, and are called homologous chromosomes, as they form zygotes.

Mitosis

Key definitions

Mitosis is nuclear division giving rise to **genetically identical** cells in which the chromosome number is maintained.

Mitosis is crucial for growth, repair, and replacement of worn-out cells in organisms. It's a process that starts with a single cell, divides into multiple cells, and is also used by asexual reproduction to create more cells.



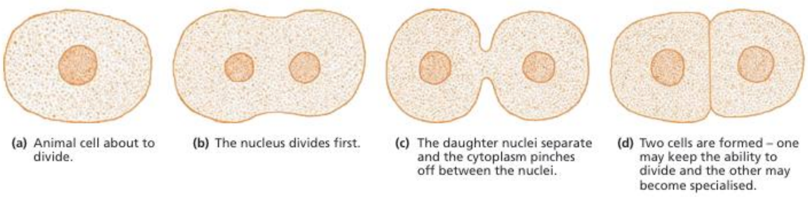
▲ **Figure 16.3** Chromosomes of different species. **Note:** The chromosomes are always in pairs

Cell division

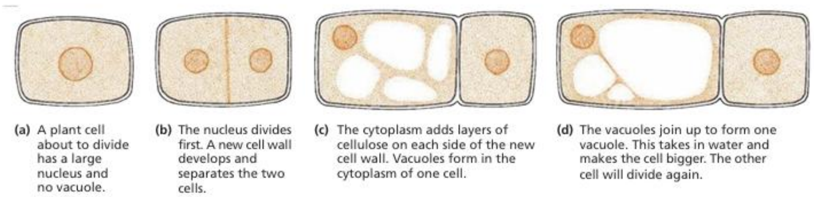
Plants and animals grow by dividing their cells, forming regions like bones, skin layers, root tips, and buds. Before cell division by mitosis, exact copies of chromosomes form parallel strands. During mitosis, chromosome copies separate, maintaining the number in each daughter cell. Each cell divides, but one cell usually grows and changes shape and structure.

Each cell divides to produce two daughter cells. Both daughter cells may divide again, but usually one of the cells grows and changes its shape and structure. In this way it becomes adapted to do one specific job – in other words, it becomes **specialised** (Figure 16.4).

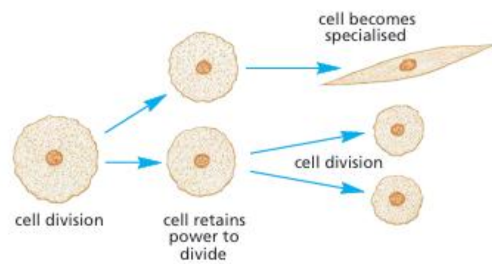
Cell division in animal and plant cells involves forming a new wall and vacuole between daughter cells, preventing cytoplasm pinching off, and sharing organelles like mitochondria and chloroplasts between daughter cells.



▲ **Figure 16.5** Cell division in an animal cell



▲ **Figure 16.6** Cell division in a plant cell



▲ **Figure 16.4** Cell division and specialisation. Cells that keep the ability to divide are sometimes called stem cells

Stem cells

Recent advancements in tissue culture involve stem cells, unspecialized cells that divide by mitosis to produce daughter cells for specific functions. Examples include skin basal cells and red bone marrow cells. Culture of these stem cells could lead to effective therapies by introducing healthy cells to replace diseased or damaged cells.

> **Key definitions**
> **Stem cells** are unspecialised cells that divide by mitosis to produce daughter cells that can become specialised for specific functions.

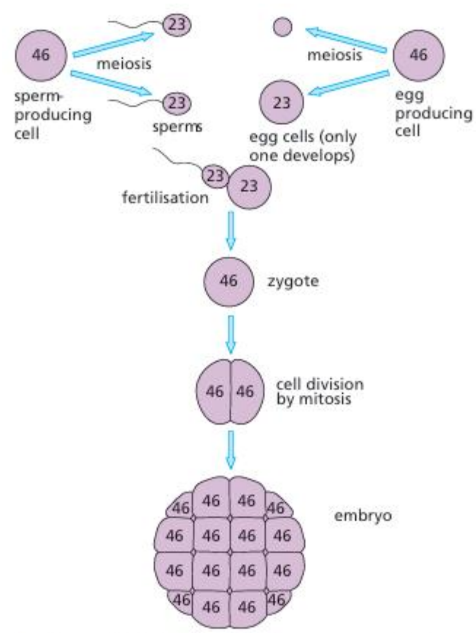
Cancers

Cancers form due to uncontrolled cell division in affected tissue, such as skin cancer. Faulty signaling can lead to excessive cell division, resulting in a lump called a tumor.

Meiosis

Meiosis takes place in the testes and ovaries of mammals, and the **anthers** and **ovules** of flowering plants. The cells formed are gametes (sperm and egg cells in mammals; ovule and **pollen** grain nuclei in flowering plants). Gametes are different from other cells because they have half the normal number of chromosomes (they are haploid).

> **Key definitions**
> **Meiosis** is a reduction division in which the chromosome number is halved from diploid to haploid, resulting in genetically different cells.



▲ **Figure 16.8** Chromosomes in gamete production and fertilisation

▼ **Table 16.1** Mitosis and meiosis compared

Meiosis	Mitosis
occurs in the final stages of cell division leading to production of gametes	occurs during cell division of somatic (body) cells
only half the chromosomes are passed on to the daughter cells, i.e. the haploid number of chromosomes	a full set of chromosomes is passed on to each daughter cell; this is the diploid number of chromosomes
homologous chromosomes and their genes are randomly assorted between the gametes	the chromosomes and genes in each daughter cell are identical
new organisms produced by meiosis in **sexual reproduction** will show variations from each other and from their parents	if new organisms are produced by mitosis in **asexual reproduction** (e.g. bulbs) they will all be like each other and their parents; they are said to be 'clones'

Asexual reproduction

Bacteria reproduce through cell division, with each cell becoming an independent organism. In more complex organisms, parts of the body may grow into separate individuals. Asexual reproduction, without the formation of gametes, can lead to the contamination of food products, as a small number of bacteria can rapidly divide into large colonies.

Asexual reproduction in flowering plants (vegetative propagation)

All flowering plants reproduce sexually, which is why they have flowers. However, many of them also have asexual methods.

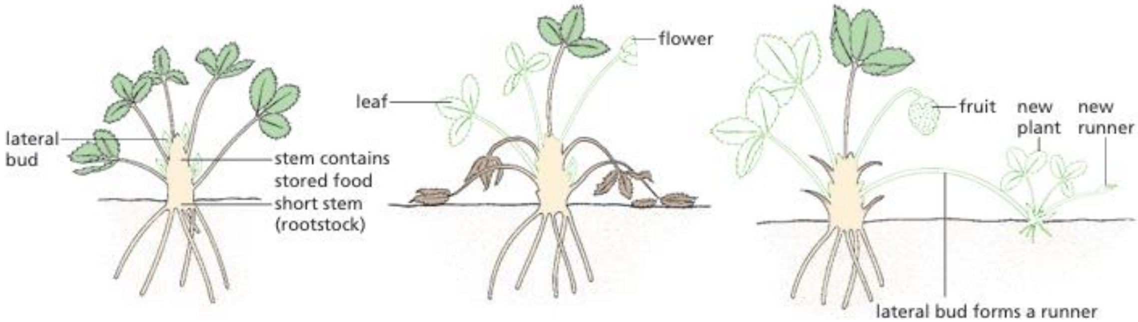
Several of these asexual methods (also called vegetative propagation) are described below. When asexual reproduction takes place naturally, it usually results from the growth of a lateral bud on a stem which is close to, or under, the soil.

An unusual method of vegetative propagation is shown by Bryophyllum (Figure 16.14).

▲ **Figure 16.14** *Bryophyllum*. The plantlets are produced from the leaf margin. When they fall to the soil below, they grow into independent plants

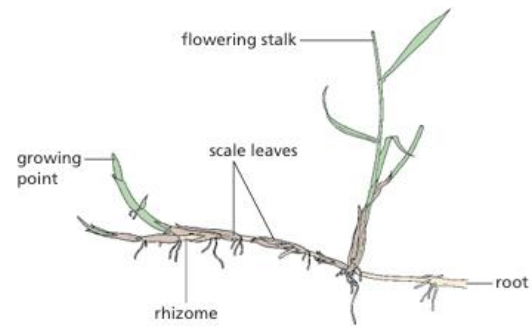
Runners and rhizomes

Strawberry and creeping buttercup plants have short, below-ground flowering shoots with leaves and flowers. Later, lateral buds produce runners, which grow horizontally over the ground. Each node has a bud that produces shoots and roots. A complete plant takes root at the node, and the parent plant provides nutrients. The runner eventually withers, leaving an independent daughter plant.



▲ **Figure 16.15** Strawberry runner developing from the parent plant

Plants produce horizontal shoots from lateral buds, called rhizomes, which grow underground and produce shoots above the ground. These shoots become independent plants when the connecting rhizome dies. Examples include couch grass and bracken, where all stems are horizontal and below ground.

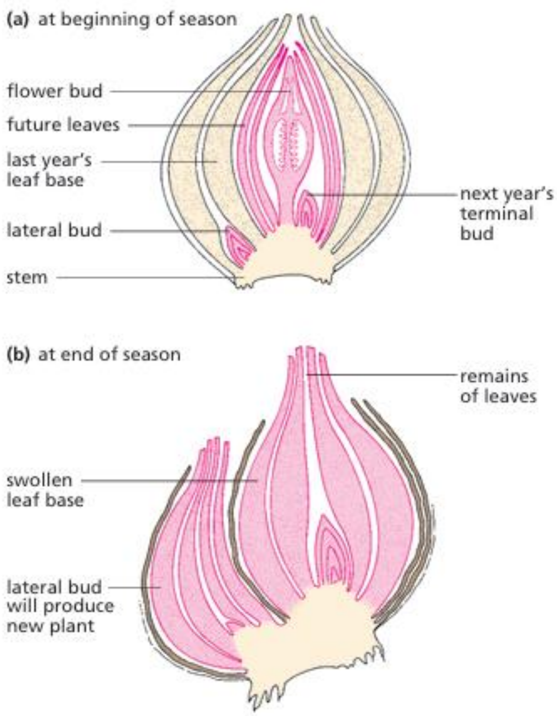


▲ **Figure 16.16** Couch grass rhizome

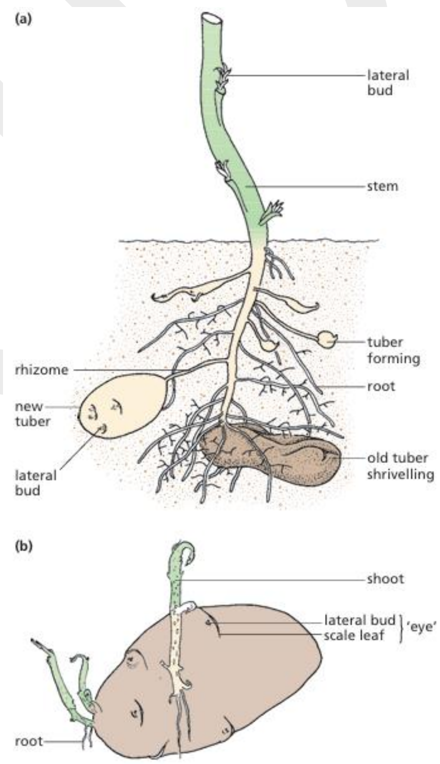
Bulbs and corms

Daffodil and lily bulbs have short shoots, a few millimetres long stem, and thick, fleshy leaves with stored food. In spring, a terminal bud uses stored food to produce a flowering stalk and leaves. Food is stored in leaf bases, forming new bulbs for next year's growth.

Crocuses and Colocasia corms have life cycles similar to bulbs, with stems swelling with stored food. Asexual reproduction occurs when a lateral bud grows into an independent plant. Organs associated with asexual reproduction serve as food stores, enabling rapid growth in spring. Potatoes are stem tubers, producing underground shoots (rhizomes) and tubers, which produce shoots using stored food.



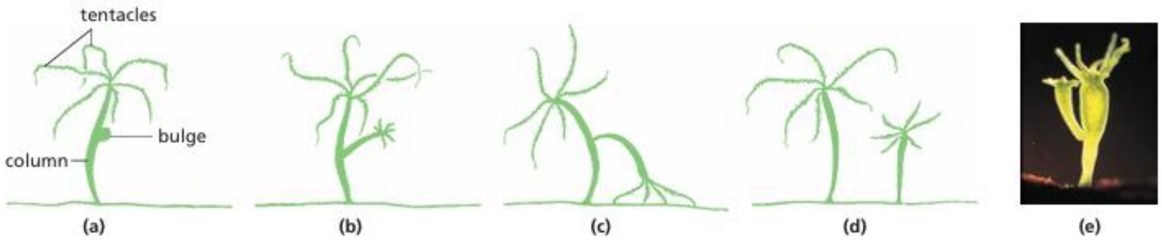
▲ **Figure 16.17** Daffodil bulb; vegetative reproduction



▲ **Figure 16.18** Stem tubers growing on a potato plant and a potato tuber sprouting

Asexual reproduction in animals

Some species of invertebrate animals can reproduce asexually. Hydra is a small animal, 5–10 mm long, which lives in ponds attached to pondweed. It traps small animals with its tentacles, swallows and digests them. Hydra reproduces sexually by releasing its male and female gametes into the water, but it also has an asexual method, which is shown in Figure 16.22.



a the group of cells on the column start dividing rapidly and produce a swelling
b the swelling develops tentacles
c the daughter *Hydra* pulls itself off the parent
d the daughter becomes an independent animal
e *Hydra* with bud

▲ **Figure 16.22** Asexual reproduction in *Hydra*

The advantages and disadvantages of asexual reproduction

In asexual reproduction no gametes are involved, and all the new plants are produced by cell division (mitosis) from only one parent. As a result, they are genetically identical; there is no variation. A population of **genetically identical** individuals produced from a single parent is called a clone. This has the advantage of preserving the good characteristics of a successful species from generation to generation. The disadvantage is that there is no variation for **natural selection** (Chapter 17) to act on in the process of evolution.

Dispersal

Asexual reproduction in plants results in offspring in suitable environments, but lacks a dispersal mechanism, leading to dense colonies competing for water and ions. Asexual plants also produce flowers and seeds, allowing them to colonize distant habitats.

Food storage

The store of food in tubers, tap roots, bulbs, etc. allows the plants to grow rapidly as soon as conditions become suitable. Early growth allows the plant to flower and produce seeds before it has to compete strongly with other plants (for water, mineral ions and light).

▼ **Table 16.2** Summary: advantages and disadvantages of asexual reproduction

Advantages	Disadvantages
No mate is needed. No gametes are needed. All the good characteristics of the parent are passed on to the offspring. This results in uniform crops and stable varieties. Where there is no dispersal (e.g. with potato tubers), offspring will grow in the same favourable environment as the parent. Plants that reproduce asexually usually store large amounts of food that allow rapid growth when conditions are suitable.	There is little variation created, so adaptation to a changing environment (evolution) is unlikely. If the parent has no resistance to a particular disease, none of the offspring will have resistance. This could affect all of a crop. Lack of dispersal (e.g. with potato tubers) can lead to **competition** for nutrients, water and light.

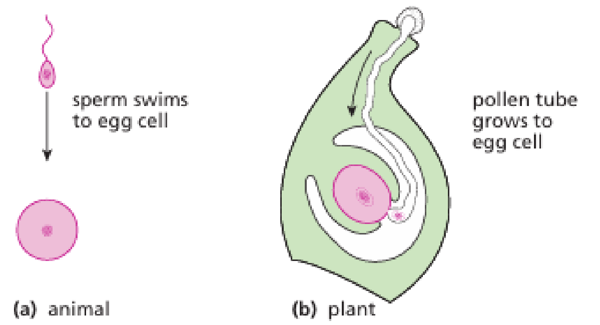
Sexual reproduction

Sexual reproduction involves the production of gametes, which are sex cells made in reproductive organs through meiosis. Male and female gametes **fuse** to form a zygote, which grows into a new individual. Male gametes are found in pollen grains, while female gametes are found in ovules.

Key definitions

Sexual reproduction is a process involving the fusion of haploid nuclei (fertilisation) to form a diploid zygote and the production of genetically different offspring.

In both plants and animals, the male gamete is microscopic and mobile (i.e. can move from one place to another). The sperm swim to the egg cell; the pollen cell moves down the **pollen tube** (Figure 16.23).



▲ **Figure 16.23** The male gamete is small and mobile; the female gamete is larger

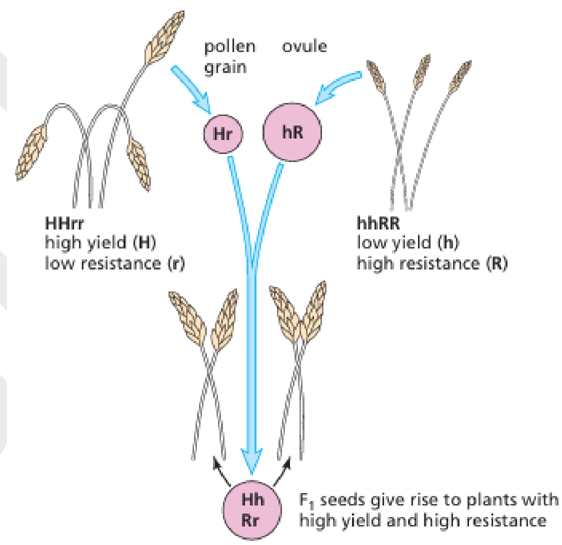
Chromosome numbers

In normal body cells (somatic cells) the chromosomes are present in the nucleus in pairs. Humans, for example, have 46 chromosomes: 23 pairs. Maize (sweetcorn) has 10 pairs. This is known as the **diploid** number. When gametes are formed, the number of chromosomes in the nucleus of each sex cell is halved. This is the **haploid** number.

The advantages and disadvantages of sexual reproduction

Plant gametes, produced from the same or different plants, produce variation in offspring due to new combinations of characteristics. Some combinations may produce less successful individuals, while others have greater survival value or can thrive in new environments. Sexually produced plants may have disease resistance, resulting in more offspring. Seeds from sexual reproduction can be scattered across a wide range, but most methods result in seed populations forming new habitats.

The seeds produced by sexual reproduction all contain some stored food, but it is quickly used up during **germination**, which only produces a small plant.



▲ **Figure 16.24** Combining useful characteristics

Crossbreeding

Biologists can use genetics to create new plant and animal varieties. For instance, cross-pollinating two wheat varieties can produce disease-resistant offspring with good grain yield, provided **dominant** genes control useful characteristics. This approach allows for improved crop yields.

A long-term disadvantage of **selective breeding** is the loss of variability. By removing all the offspring who do not bear the desired characteristics, many genes are lost from the population.

▼ **Table 16.3** Summary: advantages and disadvantages of sexual reproduction

Advantages	Disadvantages
There is variation in the offspring, so adaptation to a changing or new environment is likely, enabling survival of the species.	Two parents are usually needed (though not always – some plants can self-pollinate).
New varieties can be created, which may have resistance to disease.	Growth of a new plant to maturity from a seed is slow.
In plants, seeds are produced, which allow dispersal away from the parent plant, reducing competition.	

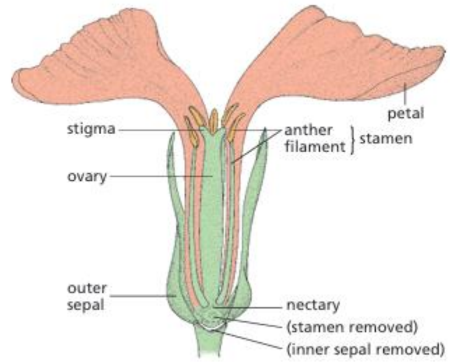
Sexual reproduction in plants

Flowers are reproductive structures; they contain the reproductive organs of the plant. The male organs are the **stamens**, which produce pollen. The female organs are the carpels.

Plants have unisexual flowers, with one flower containing either stamens or carpels. Male and female flowers can be present on the same plant, like in hazel or willow trees. Pollen grains carry male gametes to female for fertilization, forming seeds.

Key definitions

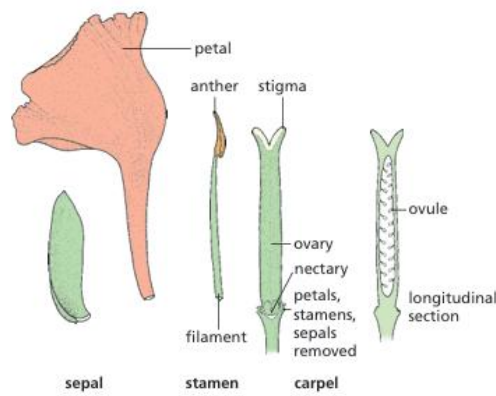
Pollination is the transfer of pollen grains from an anther to a **stigma**.



▲ **Figure 16.25** Wallflower; structure of flower (one sepal, two petals and stamen removed)

Flower structure

The basic structure of a flower is shown in Figures 16.26 and 16.28.

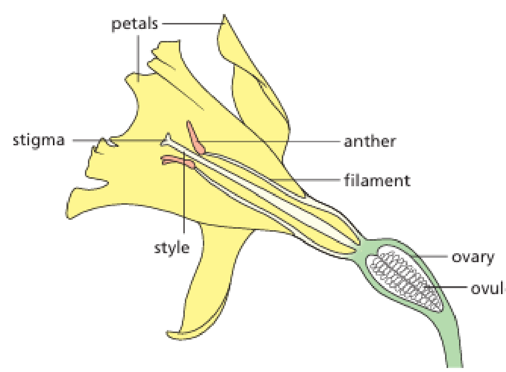


▲ **Figure 16.26** Floral parts of wallflower

Petals

Petals in flowers are brightly colored and sometimes scented, arranged in circles or cylinders. They attract insects and may pollinate the flower. In contrast, grasses and trees have leaf-like structures surrounding reproductive organs, without petals.

▲ **Figure 16.27** Daffodil flower cut in half. The inner petals form a tube. Three stamens are visible round the long style and the ovary contains many ovules



▲ **Figure 16.28** Daffodil flower. In daffodils, lilies, tulips, etc. (monocots) there is no distinction between sepals and petals

Sepals

Outside the petals is a ring of **sepals**. They are often green and much smaller than the petals. They may protect the flower when it is in the bud.

Stamens

The stamens are the male reproductive organs of a flower. Each stamen has a stalk called the filament with an anther on the end. Flowers like the Tea flower and Sacred lotus have many stamens; others like the tulip have a small number, often the same as the number of petals or sepals.

Pollen

Pollen contains the male gamete. **Insect-pollinated flowers** tend to produce smaller amounts of pollen grains (Figure 16.29(a)). These are often round and sticky or covered in tiny spikes to attach to the furry bodies of insects.

Carpels

These are the female reproductive organs. Flowers like the buttercup and blackberry have many carpels while others, like the lupin and Hibiscus, have a single carpel. Each carpel consists of an ovary, bearing a **style** and a stigma.

The ovary in blackberries contains one or more ovules, which become seeds and the entire ovary becomes a fruit. The style and stigma, attached to the top, are sticky and stick to pollen grains during pollination.

(a) insect-borne pollen grains (b) wind-borne pollen grains

▲ **Figure 16.29** Pollen grains

Receptacle

The flower structures just described are all attached to the expanded end of a flower stalk. This is called the receptacle and, in a few cases after fertilisation, it becomes fleshy and edible (e.g. apple and pear). The main functions of the parts of a flower are summarised in Table 16.4.

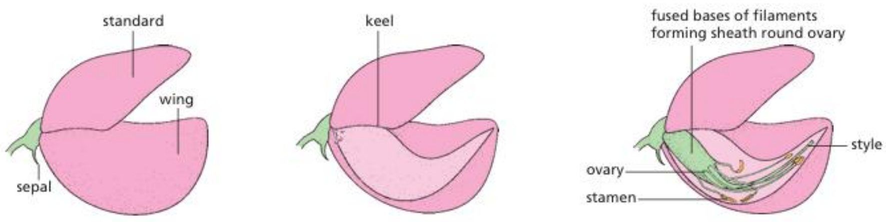
▼ **Table 16.4** The main functions of the parts of a flower

Part	Function
petal	often large and coloured to attract insects
sepal	protects the flower while in bud
stamen	the male reproductive part of the flower, made up of the anther and the filament
anther	contains pollen sacs in which pollen grains are formed. Pollen contains male sex cells. **Note:** You need to be able to describe an anther
filament	supports the anther
carpel	the female reproductive part of the flower, made up of the stigma, style and ovary
stigma	a sticky surface that receives pollen during pollination. **Note:** You need to be able to describe a stigma
style	links the stigma to the ovary through which pollen tubes grow
ovary	contains ovules
ovule	contains a haploid nucleus, which develops into a seed when fertilised

Lupin

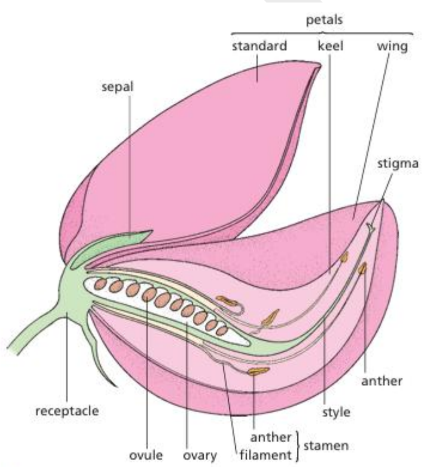
The lupin flower features five joined sepals, five petals with varying shapes and sizes, a single carpel, and a pod-shaped ovary with ten ovules. It ends in a stigma inside the boat-shaped keel and has a single carpel.

There are ten stamens: five long ones and five short ones. Their filaments are joined at the base to form a sheath around the ovary. The flowers of peas and beans are very similar to lupin flowers.



(a) intact (b) one wing removed (c) one side of keel removed

▲ **Figure 16.31** Lupin flower dissected

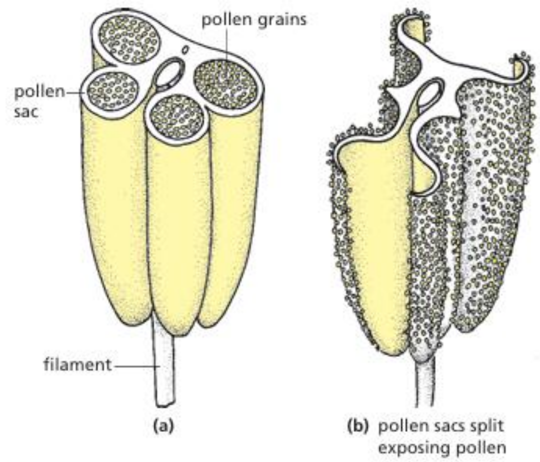


▲ **Figure 16.30** Half-flower of lupin

▲ **Figure 16.32** Lupin inflorescence. There are a hundred or more flowers in each inflorescence. The youngest flowers, at the top, have not yet opened. The oldest flowers are at the bottom and have already been pollinated

Pollination

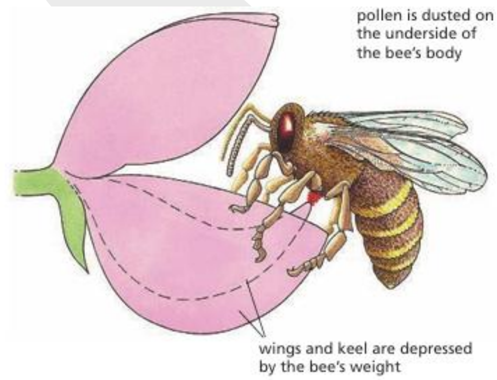
Pollination is the transfer of pollen grains from an anther to a stigma. The anthers split open, exposing the microscopic pollen grains (Figure 16.33). The pollen grains are then carried away on the bodies of insects, or simply blown by the wind, and may land on the stigma of another flower.



▲ **Figure 16.33** Structure of an anther (top cut off)

Insect pollination

Lupin flowers lack nectar and are pollinated by bees. Bees collect pollen from the anthers of the keel, pushing it onto the underside of the bee. The pollen grains stick to the bee's body, and when the bee's weight pushes the keel down, only the stigma touches the insect's body, picking up pollen grains. Lupin and wallflower are examples of insect-pollinated flowers.



▲ **Figure 16.34** Pollination of the lupin

Wind pollination

Grasses, cereals, and trees are pollinated by wind currents, not insects. They have small, green, leaf-like bracts with no nectar. Pollen grains are light and smooth, allowing them to be carried long distances. In grasses, feathery stigmas trap pollen grains, while in trees, anthers hang outside, and pollen sacs split. Shaking branches can reveal a shower of pollen.

▲ **Figure 16.36** Pollen shower from a noble fir tree

▲ **Figure 16.35** Grass flowers. **Note:** The anthers hang freely outside the bracts

Self-pollination and cross pollination

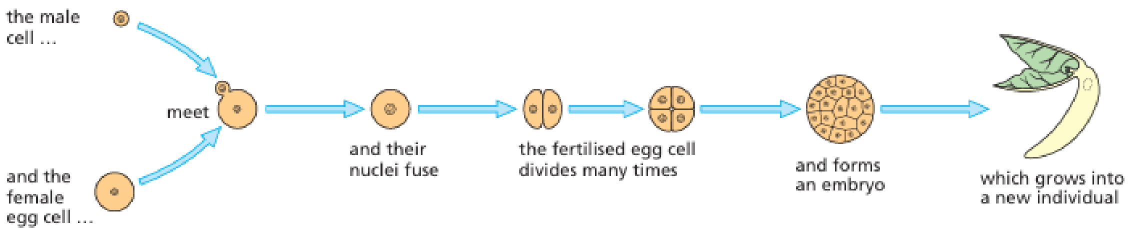
Self-pollination is the transfer of pollen grains from the anther of a flower to the stigma of the same flower, or a different flower on the same plant. **Cross-pollination** is the transfer of pollen grains from the anther of a flower to the stigma of a flower on a different plant of the same species.

Self-pollination occurs when a bee pollinates a lupin plant's flowers, while cross-pollination occurs when a bee pollinates a separate plant.

Self-pollination can occur even without pollinators, as the flower's own pollen may drop onto its stigma, allowing plants to produce seeds and prevent **extinction**.

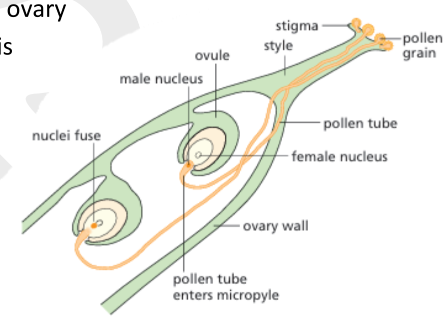
Fertilisation

Pollination occurs when pollen from an anther lands on a stigma, followed by fertilisation. Fertilisation occurs when male and female sex cells fuse, forming a zygote. This zygote develops into an embryo of an animal or plant. Gametes are the sex cells of all living organisms.



▲ **Figure 16.37** Fertilisation. The male and female gametes fuse to form a zygote, which grows into a new individual

Pollen grains absorb liquid from the stigma, forming a microscopic tube that enters the ovary and ovule. The pollen grain's nucleus combines with the egg cell's nucleus. Pollination is necessary for ovule fertilization, but not always. Bees can transfer pollen from a Bramley apple tree to a Worcester variety, resulting in successful fertilization and fruit formation.



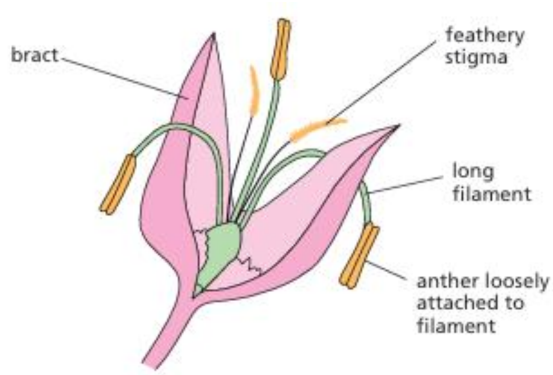
▲ **Figure 16.38** Diagram of fertilisation showing pollen tube

Adaptation

Insect-pollinated flowers undergo evolution to improve their pollination method. They have brightly colored petals and scents, which attract insects. Some produce nectar, with honey guides on petals directing insects to the source. Some flowers have modifications that adapt to pollination by only one insect species, like honeysuckle with deep petal tubes. Tube-like flowers like foxgloves require larger insects to effect pollination, with dense hairs stopping small insects from taking nectar without pollination.

Many tropical and subtropical flowers are adapted to pollination by birds, such as hummingbirds and sunbirds (Figure 16.39), or even by mammals like bats and mice.

▲ **Figure 16.39** A sunbird feeding from a tube-shaped flower



▲ **Figure 16.40** Wind-pollinated grass flower

Many grasses have anthers that are not rigidly attached to the filaments and can be shaken by the wind. The stigmas of grasses are feathery, giving a large surface area, and act as a net that traps passing pollen grains.

Table 16.5 compares the features of wind- and insect-pollinated flowers

▼ **Table 16.5** Features of wind- and insect-pollinated flowers

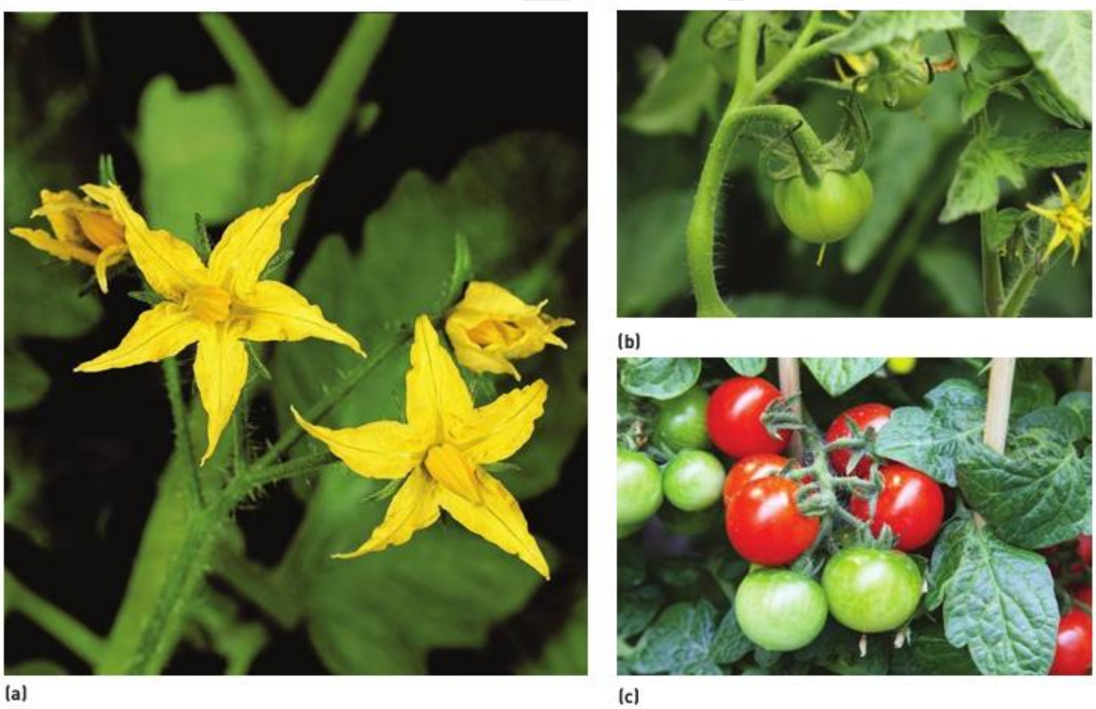
Feature	Insect-pollinated	Wind-pollinated
petals	present – often large, coloured and scented, with guidelines to guide insects into the flower	absent, or small and green
nectar	produced by nectaries to attract insects	absent
stamen	present inside the flower	long filaments allowing the anthers to hang freely outside the flower so the pollen is exposed to the wind
stigmas	small surface area; inside the flower	large and feathery; hanging outside the flower to catch pollen carried by the wind
pollen	smaller amounts; grains are often round and sticky or covered in spikes to attach to the furry bodies of insects	larger amounts of smooth and light pollen grains, which are easily carried by the wind
bracts (modified leaves)	absent	sometimes present

Fruit and seed formation

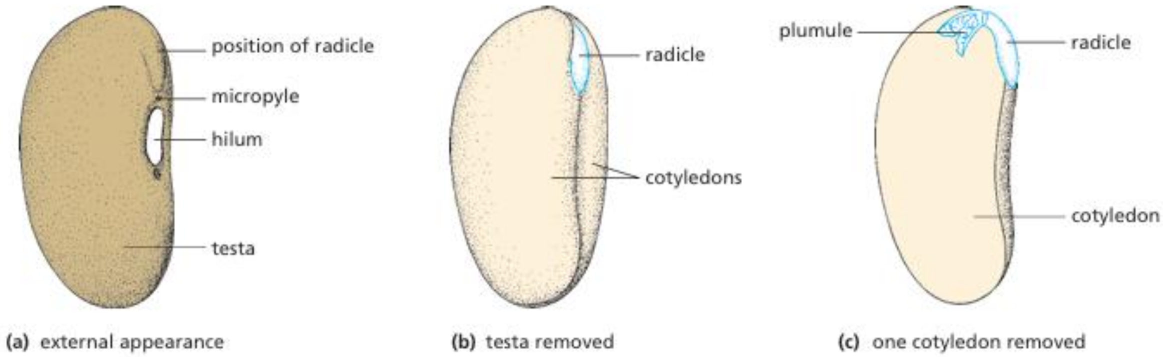
After the pollen and the egg nuclei have fused, the egg cell divides many times and produces a miniature plant called an **embryo**. This consists of a tiny root (radicle) and shoot (plumule) with two special leaves called **cotyledons**.

Cotyledons grow large enough to enclose embryos, while monocot plants store food in endosperm outside cotyledons.

In both cases the outer wall of the ovule becomes thicker and harder, and forms the seed coat or **testa**.



▲ **Figure 16.41** Tomato; fruit formation
(a) Tomato flowers – the petals of the older flowers are shrivelling
(b) After fertilisation – the petals have dropped and the ovary is growing
(c) Ripe fruit – the ovary has grown and ripened. The green sepals remain and the dried stigma is still attached.



▲ **Figure 16.42** A French bean seed

As the seeds grow, the ovary also becomes much larger, and the petals and stamens shrivel and fall off (Figure 16.41(b)). The ovary is now called a **fruit** (Figure 16.41(c)). It is not necessarily edible – the lupin ovary forms a dry pod (Figure 16.43).

▲ **Figure 16.43** Lupin flower after fertilisation. The ovary (still with the style and stigma attached) has grown much larger than the flower and the petals have shrivelled

Fruit and seed dispersal

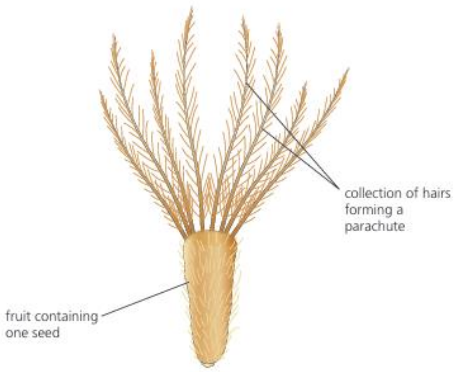
In many plants, the fruits or seeds are adapted to enable their distribution away from the parent plant. This is a means of colonising new areas. It also helps to reduce overcrowding and competition between members of the same species for light, air, water and mineral ions.

Wind dispersal

1. Parachute fruits and seeds: feathery hairs projecting from a fruit or seed increases its surface area so much that it tends to be carried by slight air currents. In some species of plant, such as Tridax, shown in Figure 16.44, the collection of hairs on the fruit is formed from the sepals of the flower.

2. Winged fruits and seeds: fruits of the Combretum (red bushwillow) plant (Figure 16.45) have extensions of the ovary wall which make a wing like structure. The extra surface area of these wings gives increased air resistance, allowing the fruit to be carried by the wind away from the parent plant.

▲ **Figure 16.45** Winged fruit of the red bushwillow plant



▲ **Figure 16.44** Tridax fruit, with a collection of hairs forming a parachute

Animal dispersal

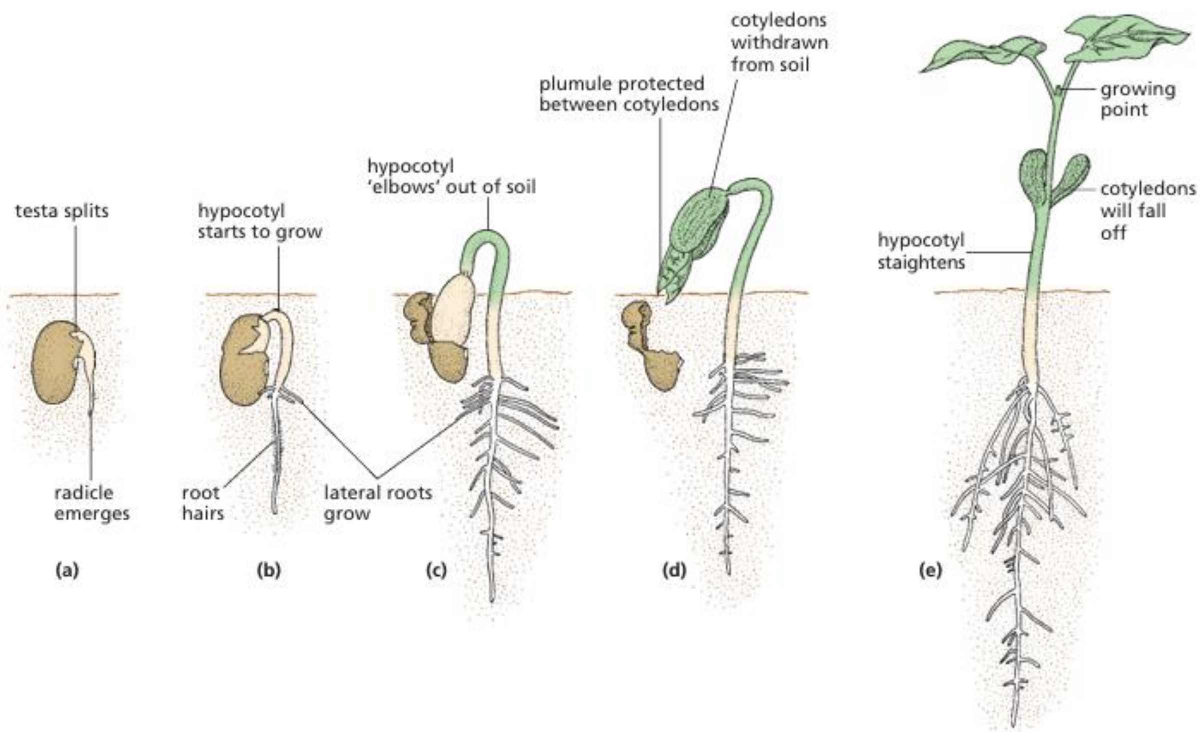
▲ **Figure 16.46** Hooked fruit of Acanthospermum

1. Hooked fruits, dispersed by mammals: the plant Acanthospermum, found in Central and South America, produces a hooked fruit (Figure 16.46). The hooks develop on the ovary wall and can catch the fur of passing mammals. At some distance from the parent plant they fall off or are brushed off by the animal.

2. Succulent fruits: these are fruits with flesh that can be eaten. They often have a brightly coloured skin to attract animals. One example is the tomato, as shown in Figure 16.41(c). The seeds inside the fruit have resistant coats, allowing them to pass through the animal's digestive system, to be dropped with the faeces some distance away from the parent plant.

Germination

Germination is the process of development of a plant from a seed. The stages of germination of a French bean are shown in Figure 16.47. A fresh seed contains only 5–20% water, compared with 80–90% in mature plant tissues. When in the soil, some seeds will absorb water and swell up, but will not start to germinate until other conditions are suitable.



▲ **Figure 16.47** Germination of a French bean

The French bean plant begins with a radicle that bursts through the testa and continues to grow into the soil, anchored by lateral roots and microscopic root hairs. The hypocotyl, a region of the embryo's stem, elongates above the radicle and moves upwards, pulling the cotyledons with it. The plumule, the seed's shoot, is protected from damage. Once the cotyledons are above the soil, the hypocotyl straightens and the leaves open out. The main food stored in the cotyledons is starch, which must be converted into soluble sugar for use by the growing shoot and root.

The importance of temperature, water and oxygen in germination

Importance of a suitable temperature In Chapter 5 it was explained that a rise in temperature speeds up most chemical reactions, including those taking place in living organisms. So, germination happens more rapidly at high temperatures, up to about 40 °C. Above 45 °C, the enzymes in the cells are denatured and the seedlings would be killed.

Importance of water

When first dispersed, most seeds contain very little water. In this dehydrated state their metabolism is very slow, and their food reserves are not used up. Dry seeds are also protected from extreme temperatures and dryness. Before the metabolic changes needed for germination can take place, seeds must absorb water.

The water that reaches the embryo and cotyledons is used to

» Activate the enzymes in the seed
» Help the conversion of stored starch to sugar, and proteins to amino acids
» Transport the sugar in solution from the cotyledons to the growing regions
» Expand the vacuoles of new cells, causing the root and shoot to grow and the leaves to expand
» Maintain the turgor (Chapter 3) of the cells. This keeps the shoot upright and the leaves expanded
» Provide the water needed for photosynthesis when the plumule and young leaves are above ground
» Transport mineral ions from the soil to the shoot.

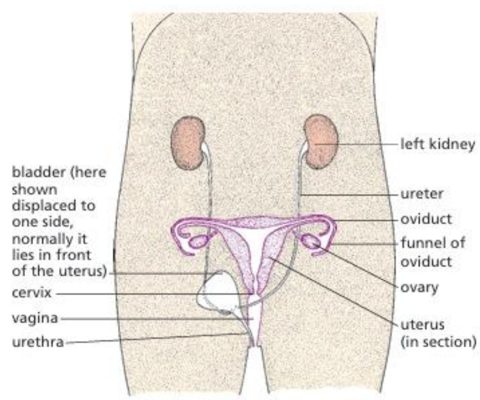
Importance of oxygen

In some seeds the seed coat is not very permeable to oxygen, which suggests that the early stages of germination are anaerobic (Chapter 10). When soaked or split open, the seed coat allows oxygen to enter. The oxygen is used in aerobic respiration.

Sexual reproduction in humans

Reproduction is the process of producing new individuals. In human reproduction, the two sexes, male and female, each produce special types of reproductive cells called gametes

Key definitions
Fertilisation is the fusion of the nuclei from a male gamete (sperm) and a female gamete (egg cell).

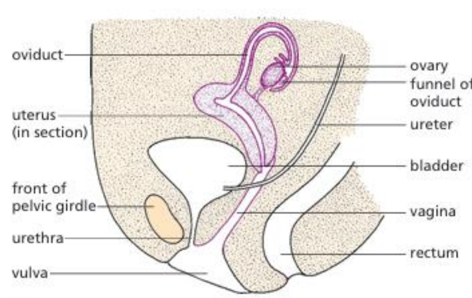


▲ **Figure 16.51** The female reproductive organs; front view

The human reproductive system

Female

Table 16.6 summarises the functions of parts of the female reproductive system. The eggs are produced from the female reproductive organs called **ovaries**. Close to each ovary is the expanded, funnel-shaped opening of the **oviduct**, the tube down which the eggs pass when released from the ovary. The oviduct is sometimes called the **fallopian tube.**



▲ **Figure 16.52** The female reproductive organs; side view

When there is no embryo developing in it, the uterus is only about 80 mm long. It leads to the outside through a muscular tube, the vagina. The **cervix** is a ring of muscle closing the lower end of the uterus where it joins the **vagina**

▼ **Table 16.6** Functions of parts of the female reproductive system

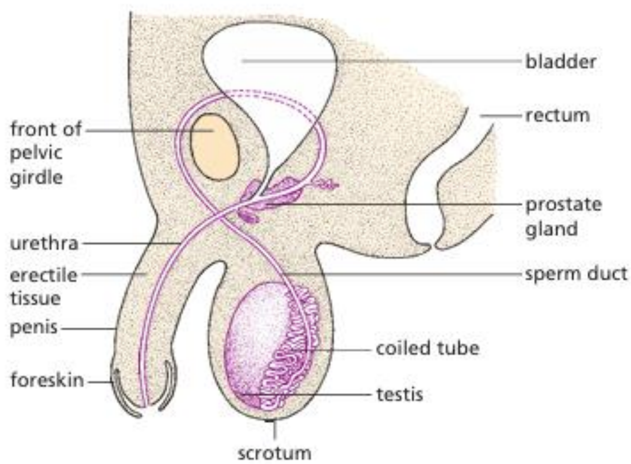
Part	Function
cervix	a ring of muscle separating the vagina from the uterus
ovary	female gonad, contains follicles in which eggs are produced
oviduct	carries an egg cell to the uterus, with propulsion provided by tiny cilia in the wall; also, the site of fertilisation
uterus	where the fetus develops
vagina	receives the male penis during sexual intercourse; sperm are deposited here

Male

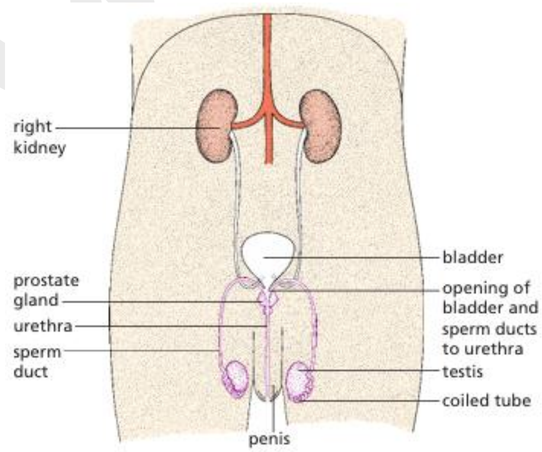
Table 16.7 summarises the functions of parts of the male reproductive system. Sperm are produced in the male reproductive organs (Figures 16.53 and 16.54), called the **testes** (singular = **testis**). These lie outside the abdominal cavity in a special sac called the **scrotum**.

The testes consist of a mass of sperm-producing tubes (Figure 16.54). These tubes join to form ducts leading to a coiled tube about 6 metres long on the outside of each testis. This tube leads into a muscular **sperm duct.**

The two sperm ducts, one from each testis, open into the top of the urethra just after it leaves the bladder. The sperm ducts enter the **prostate gland**, which surrounds the urethra at this point. The urethra passes through the **penis** and may carry either urine or sperm at different times.



▲ **Figure 16.54** The male reproductive organs; side view



▲ **Figure 16.53** The male reproductive organs; front view

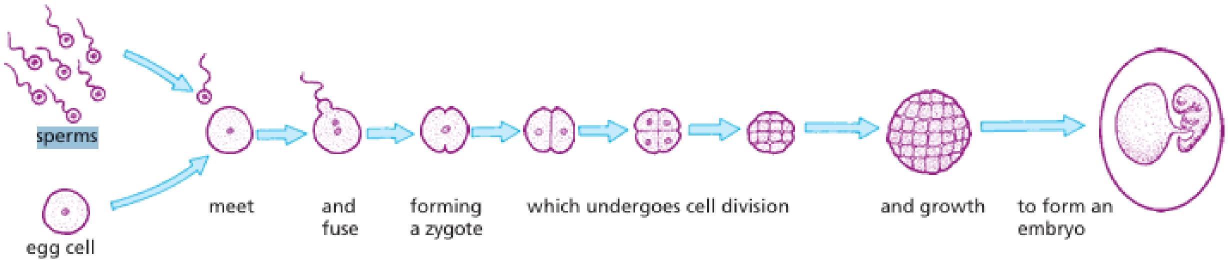
To produce a new individual, a sperm needs to reach an egg cell and fuse with it. The sperm nucleus then passes into the egg cell and the two nuclei also fuse. This is fertilisation. The cell formed after sperms the fertilisation of an egg cell by a sperm is called a **zygote**

In humans, the male produces millions of sperm, while the female produces a smaller number of eggs (usually one a month for about 40 years). Usually only one egg is fertilised at a time; two eggs being fertilised at the same time produces (non-identical) twins.

The zygote then grows into an embryo inside the body of the female.

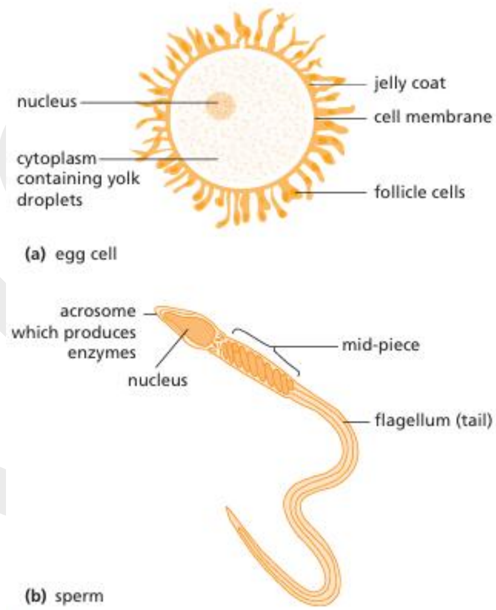
▼ **Table 16.7** Functions of parts of the male reproductive system

Part	Function
penis	can become firm to insert into the vagina of the female during sexual intercourse in order to transfer sperm
prostate gland	adds fluid and nutrients to sperm to form semen
scrotum	a sac that holds the testes outside the body, keeping them cooler than body temperature
sperm duct	muscular tube that links the testis to the urethra to allow the passage of semen containing sperm
testis	male gonad that produces sperm
urethra	passes semen containing sperm through the penis; also carries urine from the bladder



▲ **Figure 16.55** Fertilisation and development

Comparing male and female gametes



▲ **Figure 16.56** Human gametes

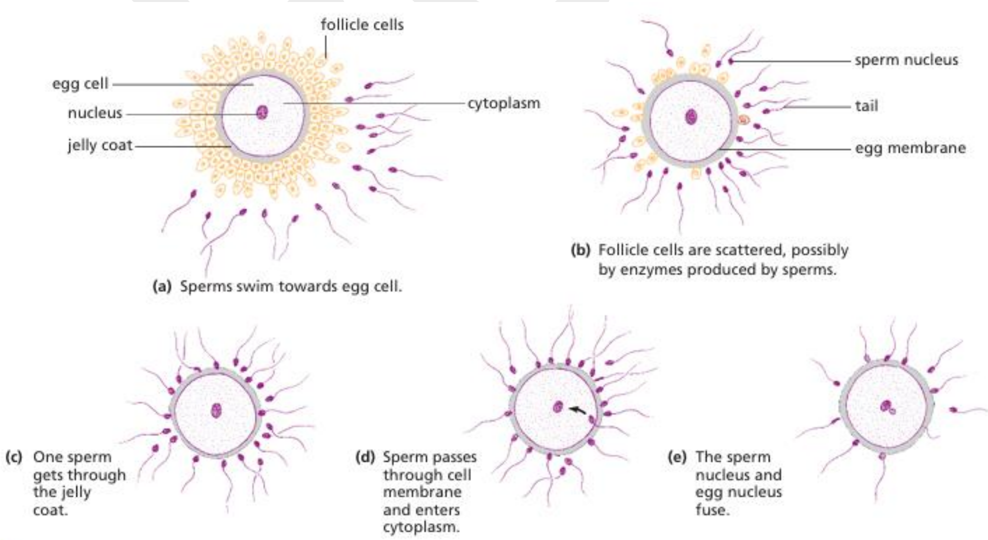
Figure 16.56(b) shows a sperm cell in detail. Sperm are much smaller than eggs and are produced in much larger numbers (over 300 million in a single ejaculation).

mid-piece of the sperm contains many mitochondria. They carry out respiration, providing energy to make the **flagellum** (tail) move and propel the sperm forward. The egg cell (see Figure 16.56(a)) is much larger than a sperm cell. Only one egg is released each month while the woman is fertile

Fertilisation

The sperm swim through the cervix and into the uterus by wriggling movements of their tails. They pass through the uterus and enter the oviduct. If there is an egg cell in the oviduct, one of the sperm may bump into it and stick to its surface.

The fertilised egg has 23 chromosomes from the mother and 23 from the father, bringing its chromosome number to 46 (the same as other human body cells). It is called a zygote.

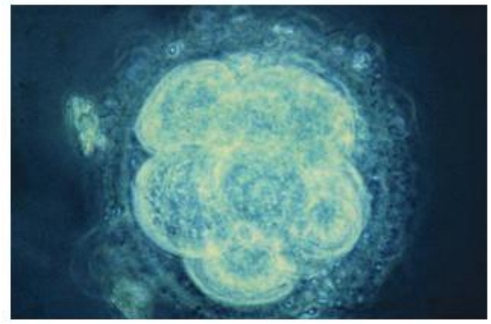


▲ **Figure 16.61** Fertilisation of an egg cell

Pregnancy and development

The cells continue to divide in this way to produce a solid ball of cells (Figure 16.62), an early stage in the development of the embryo. This early embryo travels down the oviduct to the uterus. Here it **implants** or sinks into the lining of the uterus (Figure 16.64(a)).

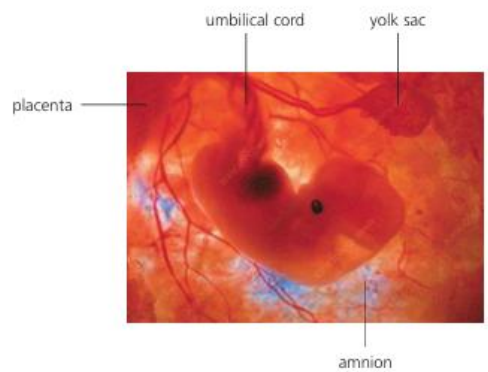
As the embryo grows, the uterus enlarges to contain it. Inside the uterus the embryo becomes enclosed in a fluid-filled sac called the **amniotic sac**, which protects it from damage and prevents unequal pressures from acting on it (Figure 16.64(b) and (c)). The fluid is called **amniotic fluid.**



▲ **Figure 16.62** Human embryo at the eight-cell stage with five of the cells clearly visible. The embryo is surrounded by the zona pellucida

Placenta

The placenta becomes closely attached to the lining of the uterus and is attached to the embryo by a tube called the **umbilical cord** (Figure 16.64(b)). Blood entering the placenta from the mother does not mix with the embryo's blood. This is important because the mother and embryo may have different blood groups. Figure 16.65 shows the human embryo at 7 weeks surrounded by the amniotic sac and placenta.

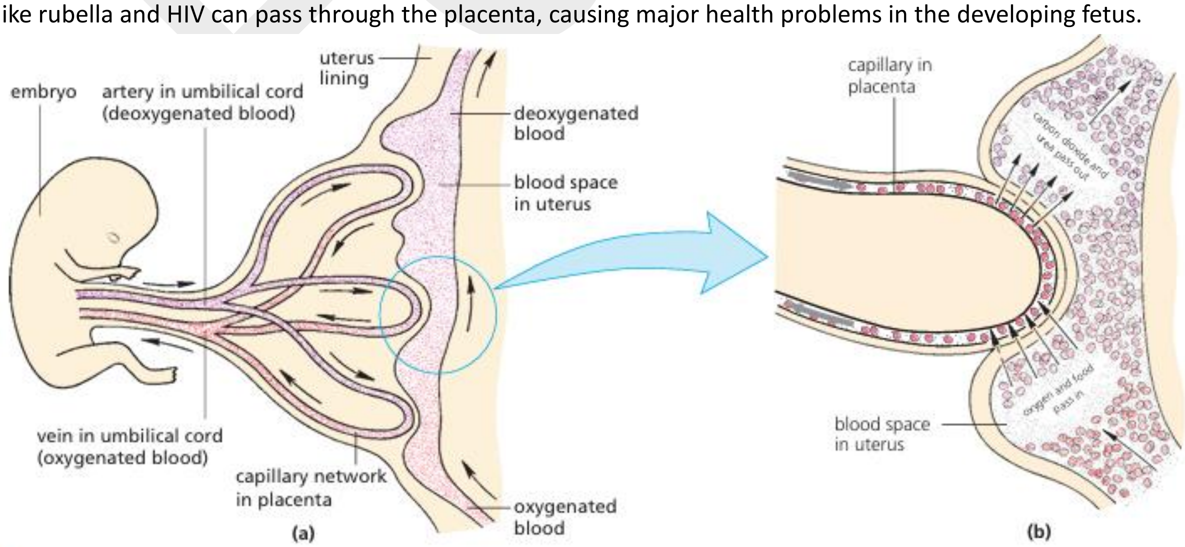


▲ **Figure 16.65** Human embryo, 7 weeks (×1.5). The embryo is surrounded by the amniotic sac. Its limbs, eye and ear-hole are clearly visible. The amniotic sac is surrounded by the placenta; the fluffy-looking structures are the placental villi, which are embedded in the lining of the uterus. The umbilical cord connects the embryo to the placenta

Functions of the placenta and umbilical cord

umbilical cord The blood vessels in the placenta are very close to the blood vessels in the uterus so that oxygen, glucose, amino acids and ions can pass from the mother's blood to the embryo's blood by diffusion (Figure 16.66(a)).

The placenta plays a crucial role in the embryonic process, allowing the exchange of substances between the mother's blood and the embryo. The mother's blood pressure doesn't damage the embryo's delicate vessels, allowing the placenta to select substances allowed to pass into the embryo's blood. However, harmful substances like alcohol, nicotine, and certain viruses like rubella and HIV can pass through the placenta, causing major health problems in the developing fetus.



▲ **Figure 16.66** The exchange of substances between the blood of the embryo and the mother

Sexual hormones in human

Puberty and the menstrual cycle

Puberty
Puberty is a stage in a woman's life where she releases eggs and oestrogens into the bloodstream, causing secondary sexual characteristics such as increased breast growth, hip widening, and hair growth. In boys, puberty occurs at the same age as girls, with testes producing sperm and releasing testosterone. Secondary sexual characteristics include enlargement of the testes and penis, deepening voice, and hair growth. Both sexes experience rapid growth during puberty. Emotional and psychological changes are also linked to the transition from child to adulthood.

The menstrual cycle

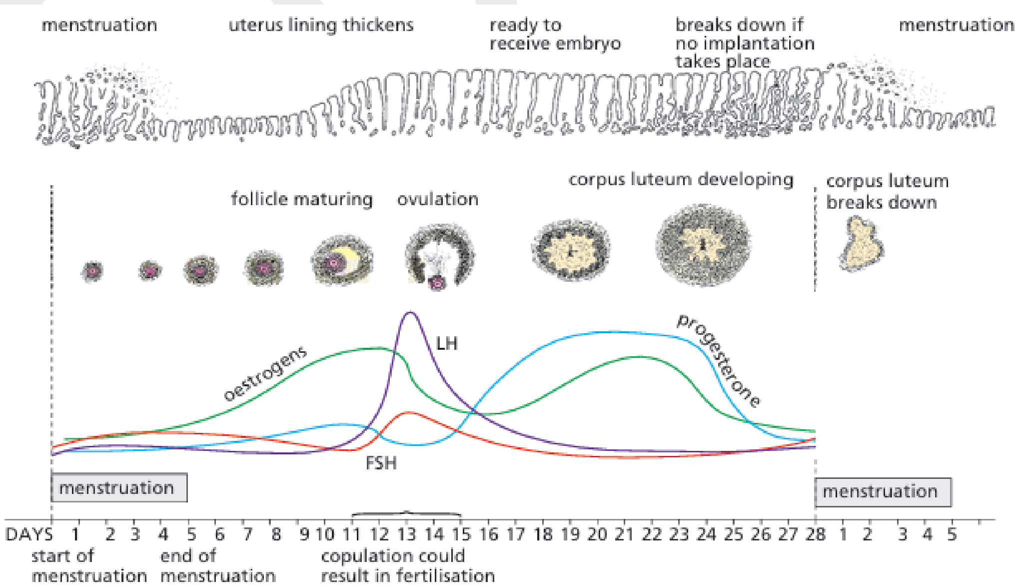
The ovaries release an egg cell about every 4 weeks. In preparation for this the lining of the uterus wall thickens. This is to enable an embryo to embed itself if the released egg cell is fertilised. If no embryo implants, the uterus lining breaks down. The cells, along with blood, are passed out of the vagina. This is called a **menstrual period**

Hormones and the menstrual cycle

At the start of the cycle, the lining of the uterus wall has broken down (menstruation). **Follicle stimulating hormone (FSH)** is then produced by the **pituitary gland** at the base of the brain and stimulates the growth of eggs in the ovaries in preparation for ovulation.

Luteinising hormone, or **lutropin (LH)** is then released from the pituitary gland. Its role is to trigger the release of the egg cell from an ovary at ovulation.

As a result, the thickened lining of the uterus breaks as a result, the thickened lining of the uterus breaks. During pregnancy, the placenta takes over the role of secreting progesterone from the corpus luteum. The ovaries continue to secrete oestrogen.



▲ **Figure 16.67** The menstrual cycle

Revision questions

1 Fig. 6.1 shows a side view of the female reproductive system.

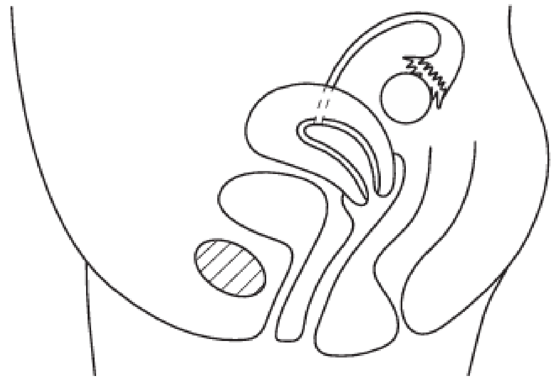


Fig. 6.1

(a) Using **label lines** and the **letters** given, label the following on Fig. 6.1.

S. where the penis is inserted during sexual intercourse

D. where a diaphragm (cap) would be placed to prevent pregnancy

M. where an ovum matures

F. where an ovum would be fertilised

E. where an embryo would become implanted

(b) Explain how

(i) the ovum passes down to the uterus,

(ii) the structure of a sperm enables it to reach the ovum,

(iii) a zygote has a diploid number of chromosomes,

(iv) The level of a hormone which prevents menstruation remains high during pregnancy, even after the corpus luteum has broken down.

2. Fig. 5.1 shows stages in the formation of a human fetus.

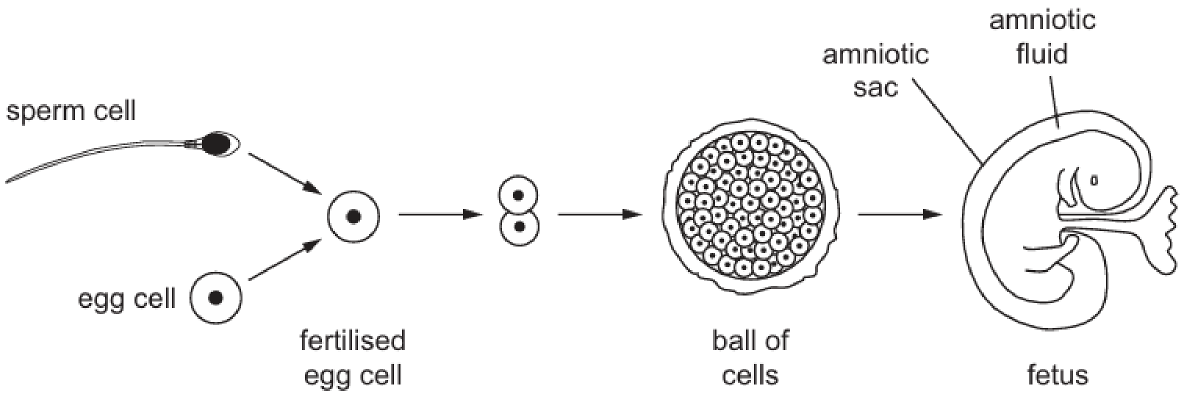


Fig. 5.1

(a) (i) Name the process of cell division that results in the formation of sperm cells.

(ii) State one way in which the sperm cell is different from cells in the developing fetus.

(iii) State the term used to describe the fertilised egg cell.

(iv) Explain what determines that a fertilised egg cell develops into a girl rather than a boy.

(b) State where each of the following is produced.

(i) the egg cell ....

(ii) the fertilised egg ....

(iii) the fetus ....

(c) The fetus is surrounded by amniotic fluid and an amniotic sac.

State their functions.

(d) (i) Outline the role of the placenta in the development of the fetus.

(ii) Describe the role of the placenta in maintaining pregnancy

3. All the plants were removed in an area of ground next to a path. Four weeks later there were 113 groundsel plants growing there. The heights of the plants were measured, sorted into groups and recorded in Table 2.1.

Table 2.1

height / cm	frequency
0 - 3.9	8
4.0 - 7.9	28
8.0 - 11.9	27
12.0 - 15.9	21
16.0 - 19.9	9
20.0 - 23.9	9
24.0 - 27.9	5
28.0 - 31.9	4
32.0 - 35.9	1
36.0 - 39.9	1

The graph, Fig. 2.1, shows the spread of data but is incomplete.

(a) Complete the graph by adding the missing column and labelling the axes

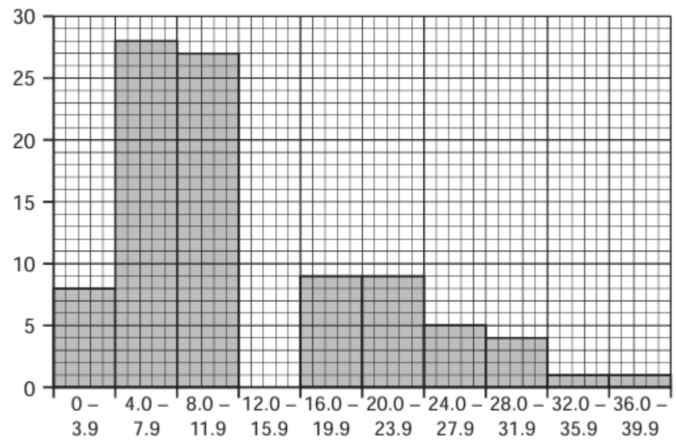


Fig. 2.1

(b) (i) State the type of variation shown by the graph.

(ii) The plants were all growing in the same soil and germinated at the same time. Suggest three reasons why the plants were not all the same height

c) Some of the plants had developed flowers that had features to attract insects.

(i) State two features a flower could have to attract insects.

(ii) State the role insects have when visiting these flowers.

(d) Some of the flowers developed seeds although insects had not visited them. Suggest how seed formation could occur in the flowers not visited by insects.

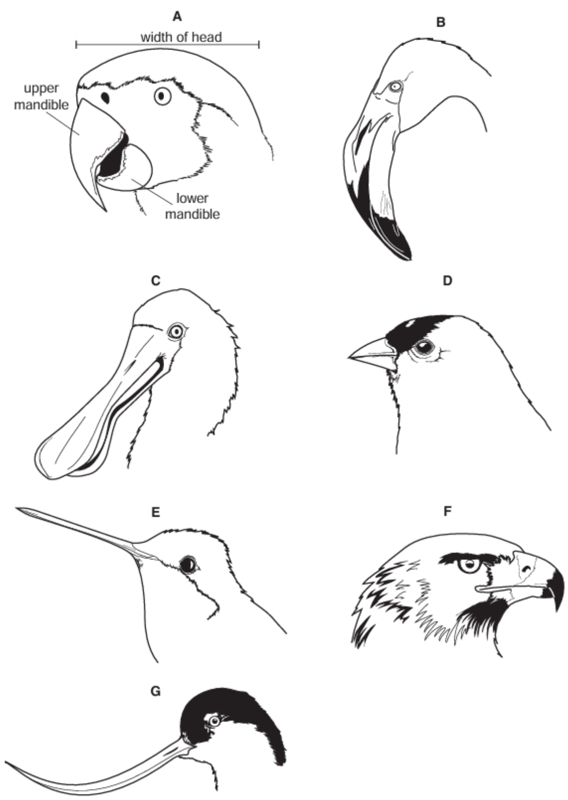
4. Fig. 1.1 shows a common emerald dove, Chalcophaps indica

Fig. 1.1

(a) Two distinguishing features of birds are beaks and wings. State one other feature shown only by birds that is visible in Fig. 1.1.

(b) Birds show variation in the sizes and shapes of their beaks. A beak is composed of an upper mandible and a lower mandible. Fig. 1.2 shows the heads of seven different species of bird.

Use the key to identify each species. Write the letter of each species (A to G) in the correct box beside the key. One has been done for you



not drawn to scale
Fig. 1.2

key

1	(a)	beak is shorter than the width of the head	go to 2	
	(b)	beak is longer than the width of the head	go to 4	
2	(a)	upper mandible is same length as the lower mandible	*Spinus tristis*	
	(b)	upper mandible is longer than the lower mandible	go to 3	
3	(a)	lower mandible is about half the length of the upper mandible	*Ara ararauna*	**A**
	(b)	lower mandible is more than half the length of the upper mandible	*Aquila chrysaetos*	
4	(a)	both mandibles widen at the end of the beak	*Platalea regia*	
	(b)	both mandibles are a similar width along their whole length	go to 5	
5	(a)	beak is straight	*Trochilus polytmus*	
	(b)	beak is curved	go to 6	
6	(a)	beak curves upwards	*Recurvirostra americana*	
	(b)	beak curves downwards	*Phoenicopterus minor*	

5) Fig. 1.3 shows the events that occur during sexual reproduction in birds. The numbers in brackets indicate the number of chromosomes in the nuclei of the cells of the common emerald dove.

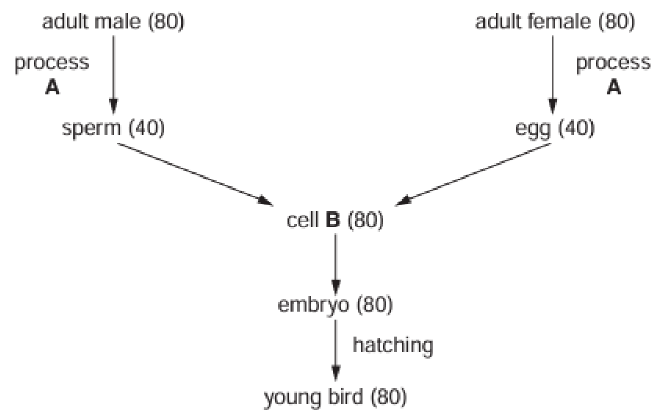


Fig. 1.3

i) Name process A and cell B

ii) State why cell B is described as a diploid cell.

(iii) The embryo of the bird develops from cell B. State what is meant by the term development.

(iv) Sexual reproduction usually leads to variation.
Explain why variation is an advantage for a species such as the common emerald dove

6. (a) Define the term genetic engineering

(b) Fig. 6.1 is a flow diagram that shows how insulin can be produced using genetic engineering

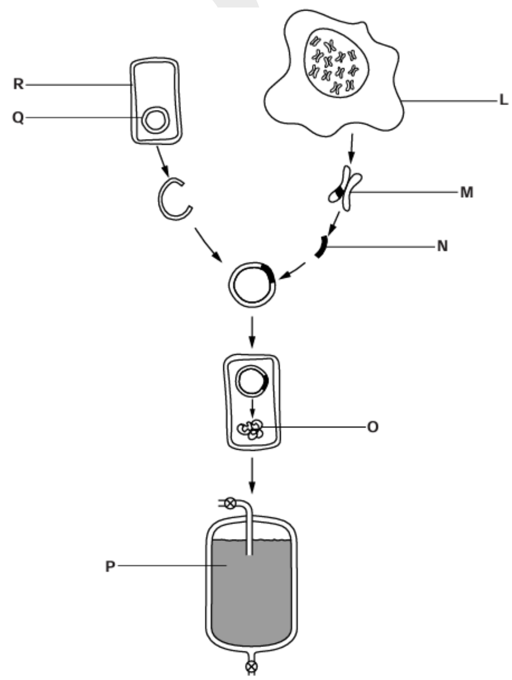


Fig. 6.1

Table 6.1 shows stages in the production of insulin by genetic engineering. Complete Table 6.1. The first row has been done for you.

Table 6.1

letter from Fig. 6.1	name	description
M	chromosomes	threads of DNA found in the nucleus
		section of DNA removed from human cell
	plasmid	
		type of cell that is genetically engineered
		specific chain of amino acids coded by the section of DNA removed from the human cell
	fermenter	

(c) The genetically engineered cells in Fig. 6.1 reproduce asexually. Explain the advantages of asexual reproduction for insulin production by genetic engineering

7. Fig. 3.1 shows a female lion in a game reserve.

Fig. 3.1

(a) (i) State one feature, visible in Fig. 3.1, which identifies the lion as a mammal.

(ii) State one other feature, not visible in Fig. 3.1, which distinguishes mammals from all other vertebrate groups.

(b) Study the eyes of the lion in Fig. 3.1.

(i) Suggest and explain what the light conditions were when the photograph was taken.

II) Explain the importance of the eyes reacting to light in this way.

c) Scientists say that lions are unable to see in colour. Suggest how a study of a lion's retina would provide evidence for this statement

(d) The lion in Fig. 3.1 was observing tourists nearby. It turned its head to see zebras moving in the distance. Describe how the eyes of the lion would adjust to focus on the zebras

8. If the glucose in the blood rises above its normal concentration, insulin is secreted to bring the concentration back to normal.

(a) (i) Suggest one explanation for a rise in the concentration of glucose in the blood.

(ii) Name the organ that secretes insulin.

III) Describe the role of the liver in bringing the concentration of glucose in the blood back to normal.

(iv) State the term that describes how a substance, such as glucose, in the body is maintained at a constant level.

(b) Diabetics are unable to control their blood glucose levels naturally.
Human insulin can now be made using bacteria that have been genetically engineered.

(i) Insulin is a protein. Suggest why insulin has to be injected rather than taken by mouth.
Explain how bacteria can be genetically engineered and used to make human insulin.