GROWTH AND DEVELOPMENT

Growth is **an irreversible and permanent increase in dry mass of living material.**

Development is an **increase in complexity.** It's accompanied by formation of new structures and cell specialization.

Starting with an individual cell, growth of a multicellular organism is divided into three phases:

1. **cell division:** an increase in cell number as a result of mitosis and cell division
2. **cell enlargement:** an irreversible increase in cell size as a result of the uptake of water or the synthesis of living material.
3. **cell differentiation:** the specialisation of cells; in its broad sense, growth also includes this phase of cell development.

A typical growth curve is s-shaped and it's called a **sigmoid** typical of much growth.

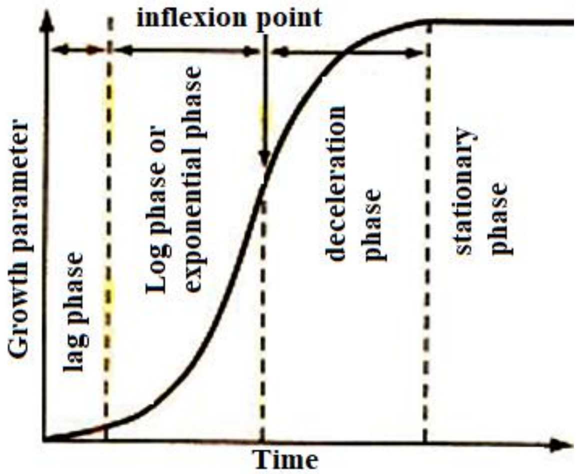
A sigmoid curve can be divided into four parts.

F**irst phase** is the **lag phase**: little growth occurs.

Second phase, the **logarithmic** or **log phase,** which growth proceeds exponentially. During this phase the rate of growth increases and at any point growth is proportional to the amount of material or number of cells already present.

The **third phase** is the **decelerating phase**: growth becomes limited as a result of the effect of some internal or external factor, or the interaction of both.

The final phase is the **plateau phase** or **stationary phase.** This usually marks the period where overall growth has ceased and the parameter under consideration remains constant. The precise nature of the curve during this phase varies, depending on the species and what is being measured.



Exceptions: The curve may continue to rise slightly until the organism **dies**, as is the case with monocotyledonous leaves, many non-vertebrates, fish and certain reptiles. This indicates continuing **positive growth**. In the case of certain **cnidarians** the curve flattens out, indicating zero growth, whilst other growth curves may tail off, indicating a period of **negative growth.** The latter pattern is characteristic of many mammals, including humans, and is a sign of physical senescence associated with

METHODS OF MEASURING GROWTH

Growth can be measured at various levels of biological organisation, such as **growth of a cell**, **organism or population**. The **numbers** of organisms in a population at different times can be counted and plotted against time to produce a population growth curve.

At the level of the organism there are a variety of parameters which may be measured; **length, area, volume and mass** are commonly used. **In plants**, growth curves for roots, stems, internodes and leaves are often required, and length and area are the parameters commonly chosen. In the case of growth in animals and plants, length and mass are two commonly measured parameters.

Using mass, two values can be used, **fresh (wet)** mass and **dry mass**. Fresh mass is the easier to measure since it requires less preparation and applicable for live organisms. However, it gives inconsistent readings due to fluctuations in water content.

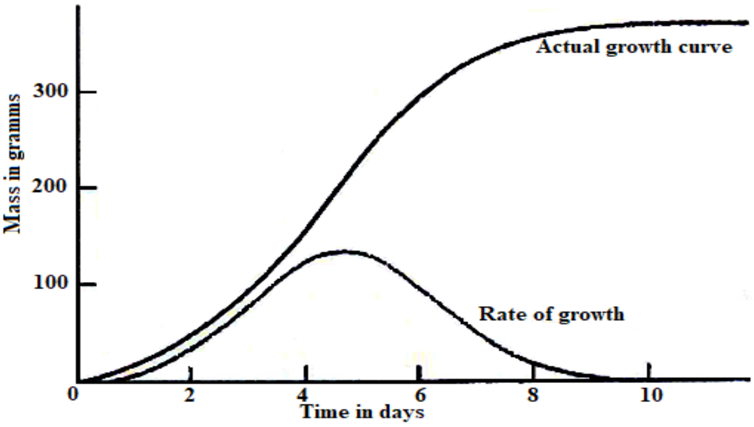
True growth is reflected by changes in the amounts of constituents **(dry mass)** other than water. This involves removing all water by drying, before weighing. It is difficult to carry out and permanently destroys the organisms involved, but does give an accurate measure of growth.

NB: Groups of organisms are sometimes used rather than an individual. For instance, e.g. growth of peas, growth of a population of yeast can be measured by counting the number of cells in a known, and very small, volume of the medium in which the yeast is growing

RATE OF GROWTH

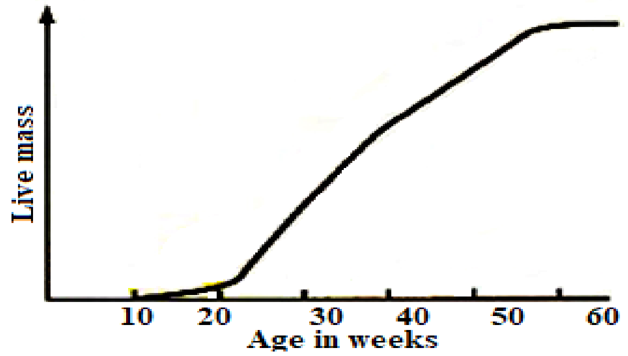
The actual growth of an organism is the cumulative increase in size over a period of time. A small annual plant, shows a typical sigmoid growth curve. **The rate of growth** is a measure of size increase over a series of equal time intervals. Instead of measuring the actual mass, increase in mass over each day period is measured. These produce a bell-shaped graph as shown.

The growth rate curve of most organisms is bell-shaped



TYPES OF GROWTH CURVE

Absolute growth curves: This shows the overall growth pattern and the extent of growth obtain by plotting data such as length, height or mass against time. The rate is measured as the change in a particular parameter, such as height or mass, in a particular time. For example, it could be the increase in height of a human over a period of a year. In particular, it shows the period when growth is most rapid and this corresponds to the steepest part of the absolute growth curve. The peak of the absolute growth curve marks the point of inflexion on the sigmoid curve after which the rate of growth decreases as the adult size is attained. Overall a bell-shaped absolute growth rate curve is obtained from a sigmoid absolute



Absolute growth curve or actual growth curve obtained by plotting live mass against age

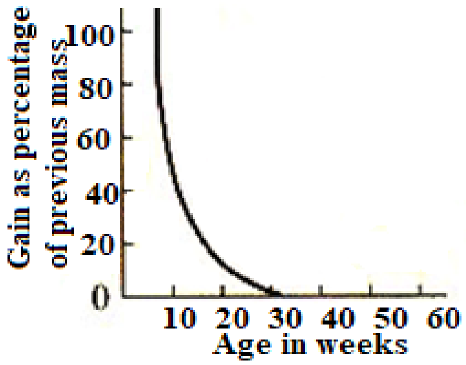
<u>Relative growth rate</u> **Relative growth rate** curve takes into account existing size. Thus if a 5-year-old and a 10-year-old human both grew 10 cm in height in one year, their absolute growth rates would be the same, but the 5 year old would be growing relatively faster and have a greater relative growth rate.

RGR=$\frac{\textit{Growth in given period of time}}{\textit{measurement at start of time period}}$

RGR=$\frac{\textit{absolute growth rate}}{\textit{original measurement}}$

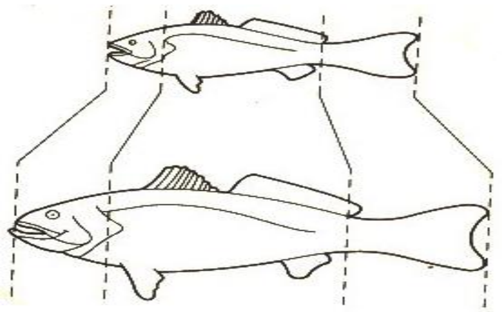
These calculations give the **relative growth rate**. Changes in relative growth rate with time can be shown on a relative growth rate curve. This is a measure of the ***efficiency*** of growth, that is the rate of growth relative to the size of the organism.

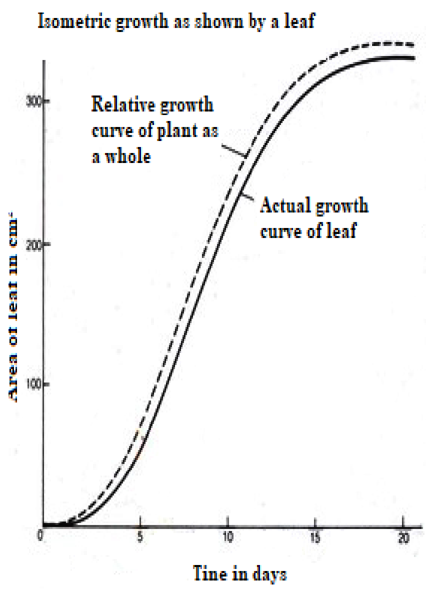
A comparison of relative growth rate curves for organisms grown or reared under different conditions shows clearly the most favourable conditions for rapid growth and for growth over an extended period.

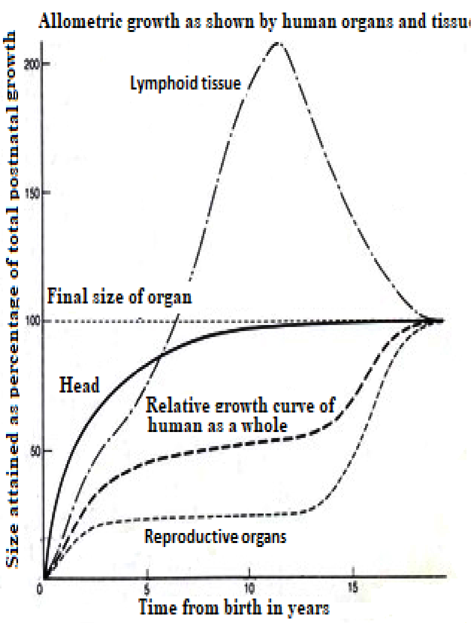


PATTERNS OF GROWTH

Isometric growth: This occurs when an organ grows at the same mean rate as the rest of the body, change in size of the organism is not accompanied by a change in shape of the organism. The relative proportions of the organs and the whole body remain the same. This is seen in fish and certain insects, such as locusts (except for wings and genitalia), there is a simple relationship between linear dimension, area, volume and mass

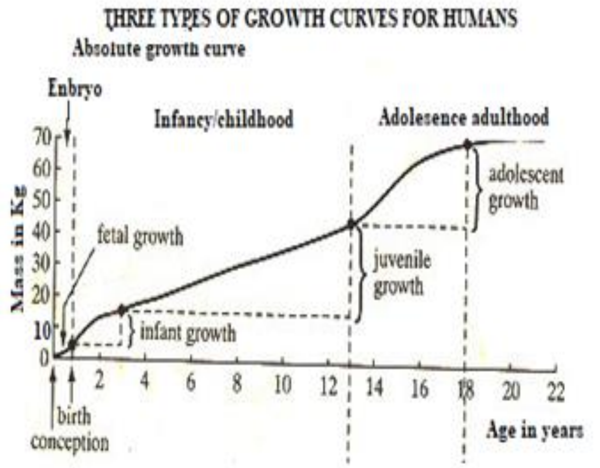


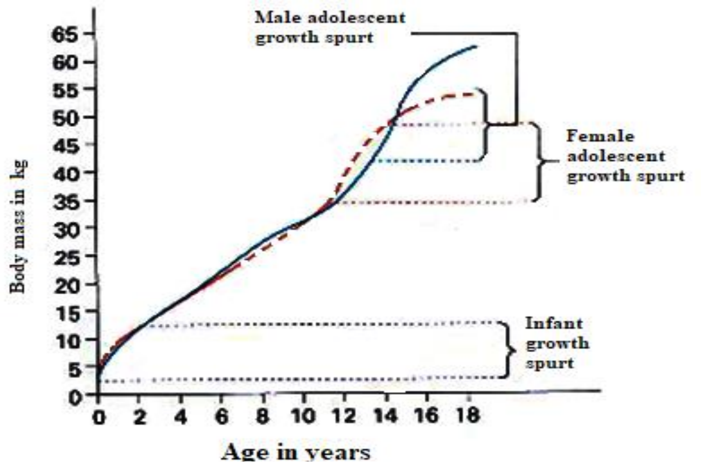


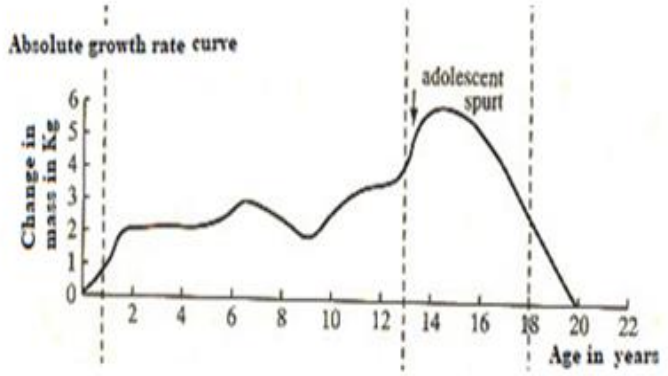


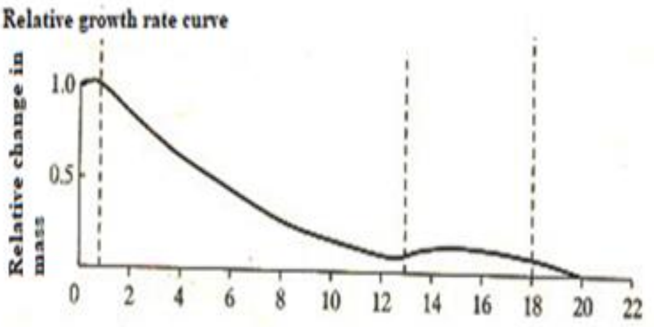
Allometric growth occurs when an organ grows at a different rate from the rest of the body. This produces a change in size of the organism which is accompanied by a change in shape of the organism. This pattern of growth is characteristic of mammals and illustrates the **relationship between growth and development.**

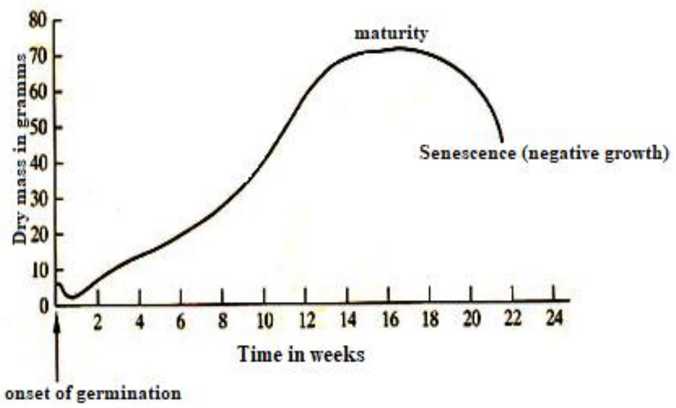
In animals, organs often exhibit **allometric** growth. Lymph tissue, which produces white blood cells to fight infection, grows rapidly in early life when the risk of disease is greater as immunity has not yet been acquired. By adult life the mass of lymph tissues is less than half of what it was in early adolescence. The reproductive organs grow very little in early life but develop rapidly with the onset of sexual maturity at puberty.











In girls' puberty occurs earlier than in boys; due to early secretion of oestrogen hormone that promotes development of reproductive organs and female sexual characteristics. In boys, the rapid increase is due to testosterone hormone; that maintains and enlarges the testes and growth of the male spurt at puberty

Growth can be positive or negative. **Positive growth** occurs when synthesis of materials (**anabolism**) exceeds breakdown of materials **(catabolism)**, whereas **negative growth** occurs when catabolism exceeds anabolism. For example, in the course of germination of a seed and the production of a seedling there is an increase in cell number, cell size, fresh mass, length, volume and complexity of form, while at the same time dry mass may actually decrease because reserves are being used up. Germination therefore includes a period of negative growth.

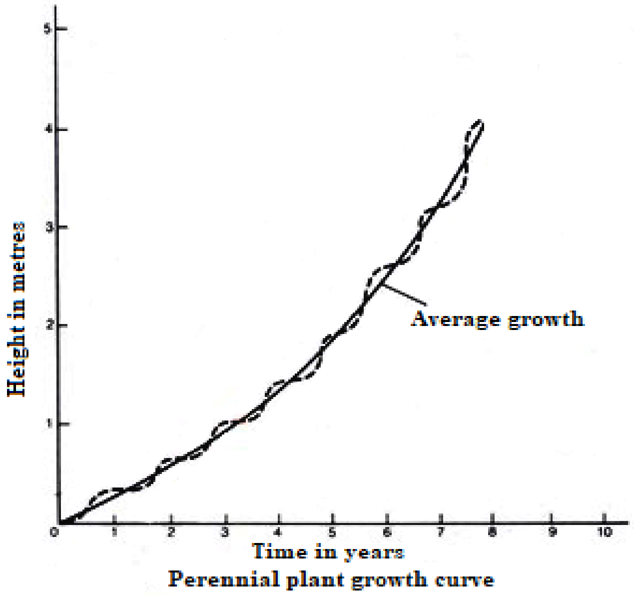
Limited and unlimited growth

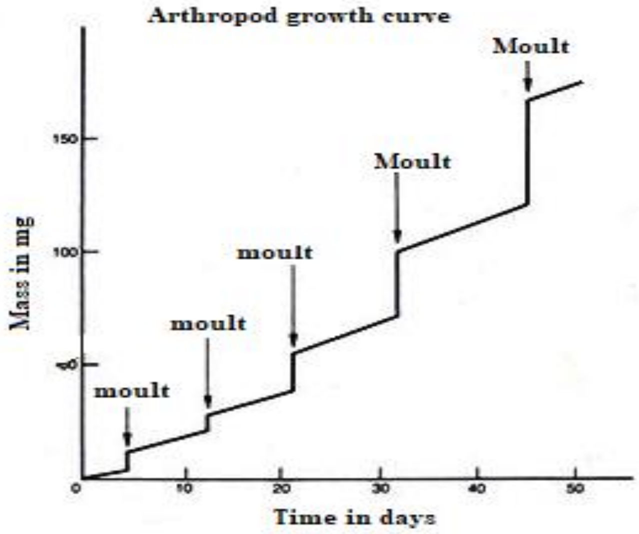
Growth in plants and animals shows two basic patterns. Limited (definite or determinate) growth and unlimited (indefinite or indeterminate) growth. **Growth in annual plants is limited** and, after the plant matures and reproduces, there is a period of **negative growth** or **senescence** before the death of the plant.

Woody perennial plants on the other hand show unlimited growth and have a characteristic growth curve which is a cumulative series of sigmoid curves each of which represents one year's growth. With unlimited growth, some slight growth continues until death. Other examples of unlimited growth are found among fungi, algae, and many animals, particularly non- vertebrates, fishes and reptiles. Monocotyledonous leaves show unlimited growth.

Growth in arthropods

Due to the inelastic nature of their exoskeletons they appear to grow only in spurts interrupted by a series of moults (**discontinuous growth**). Incomplete metamorphosis occurs when there is a series of larval stages, called instars, with each successive stage resembling the adult more closely. Moulting occurs between each stage, and growth in length is confined to the brief period before the new exoskeleton hardens. Before a new exoskeleton has fully hardened it is capable of some expansion. During this time the insect may take up water in order to expand the exoskeleton as much as possible.





GROWTH AND DEVELOPMENT IN PLANTS

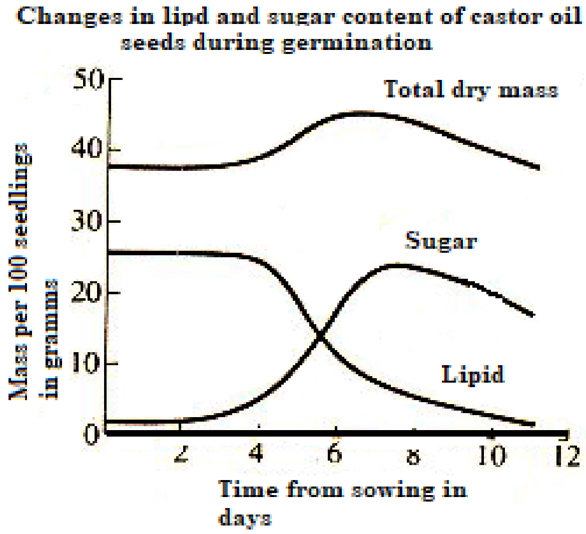
Seed dormancy: Some seeds may fail to germinate in presence of water, oxygen and suitable temperature. They are described as **dormant**. They undergo certain internal changes described as **after-ripening** before they germinate. These changes ensure that **premature germination** does not occur. Mechanisms exist which ensure that germination is **synchronised** with the onset of a season **favourable** for growth. Some of the common mechanisms are discussed below.

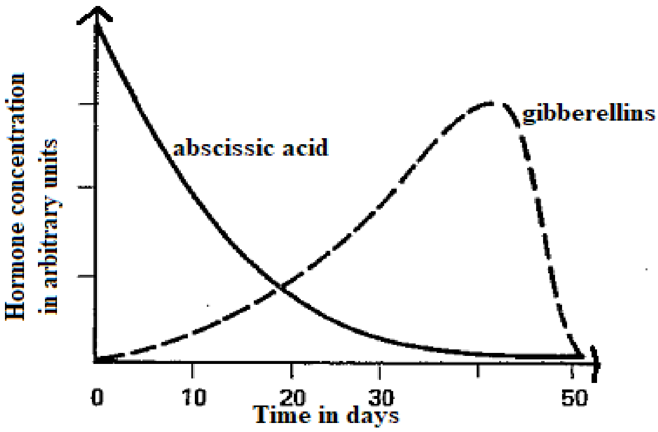
Barrier methods**:** seed testa being impervious to water or the passage of oxygen, or being physically strong which prevents growth of the embryo. Physical damage (**scarification**) to the seed coat can remove this restriction. Under natural circumstances, bacteria or passage through the gut of an animal may have the same effect. The seeds of some species are stimulated to germinate by fire.

Growth inhibitors. Fruits and seeds may contain chemical growth inhibitors which prevent germination. **Abscisic a**cid often has this role. Thorough soaking of the seeds removes the inhibitor or its effect may be overridden by an increase in a growth promoter such as gibberellin. Tomato seeds contain high levels **of abscisic acid** which prevent germination of the seeds inside the tomato fruit.

Light. The dormancy of some seeds is broken by light after water uptake, a **phytochrome** controlled response. This stimulation of germination by light is associated with a rise in gibberellin levels within the seed.
Some Seeds commonly require a cold **period**, a process known as **prechilling** before germination occurs. It is associated with a rise in gibberellin activity and sometimes a reduction in growth inhibitors. It ensures that seeds pass through a cold spell of a particular length before germination and are less likely to germinate during a warm spell in winter. Cold treatments increases permeability of the seed coat, as well as changes in levels of growth substances are involved.

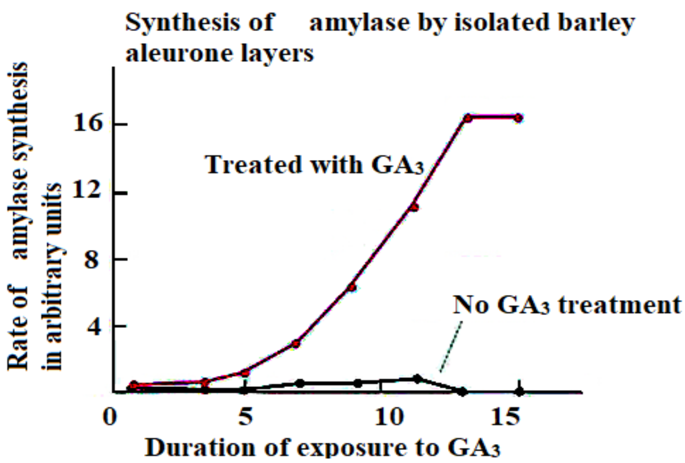
Germination is the onset of growth of the embryo, and requires water, oxygen and a temperature within a certain range (normally 5^0C to 40°C). In some seeds light is also required. Under these conditions the seed takes up water rapidly, initially by imbibition and later by osmosis.
This water causes the seed contents to swell and ruptures the testa (seed coat). **Water activates** enzymes in the seed which **hydrolyse insoluble** storage material into **soluble substance**. Proteins are converted into amino acids, carbohydrates such as starch are converted into glucose, and fats are converted into fatty acids and glycerol. The soluble products are transported to the growing point of the embryo. The glucose, fatty acids and glycerol provide respiratory substrates from which energy for growth is released. Glucose is also used in the formation of cellulose cell walls. The amino acids are used to form new enzymes and structural proteins within new cells.

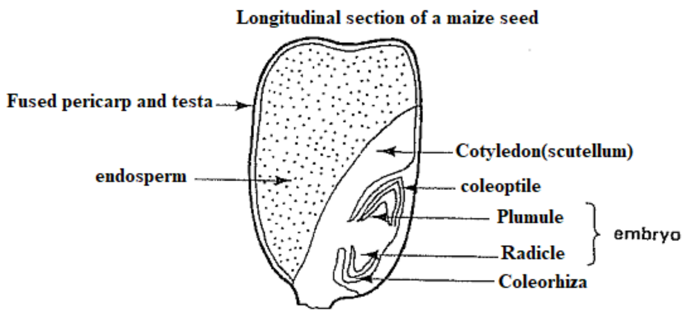


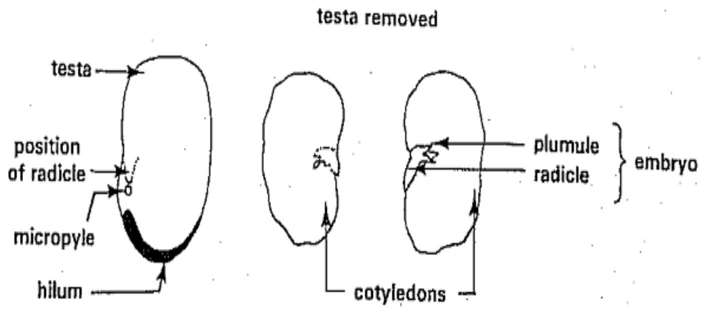


Germination of a starchy seed in barley grain, synthesis of **alpha amylase** and other enzymes takes place in the outer layers of the endosperm in response to gibberellin secreted by the embryo. These outer layers contain stored protein which is the source of amino acids for protein synthesis.

Seeds which store **lipids convert them to fatty acids and glycerol**. Each molecule of lipid yields three molecules of fatty acid and one of glycerol. Fatty acids are either oxidised directly in respiration or converted to sucrose, which is then translocated to the embryo.







Respiration in germinating seeds Rates of respiration in both storage tissues and embryo are high owing to the intense metabolic activity in both regions. Substrates for respiration may differ in each region and may also change during germination. This is revealed by changes in the respiratory quotient

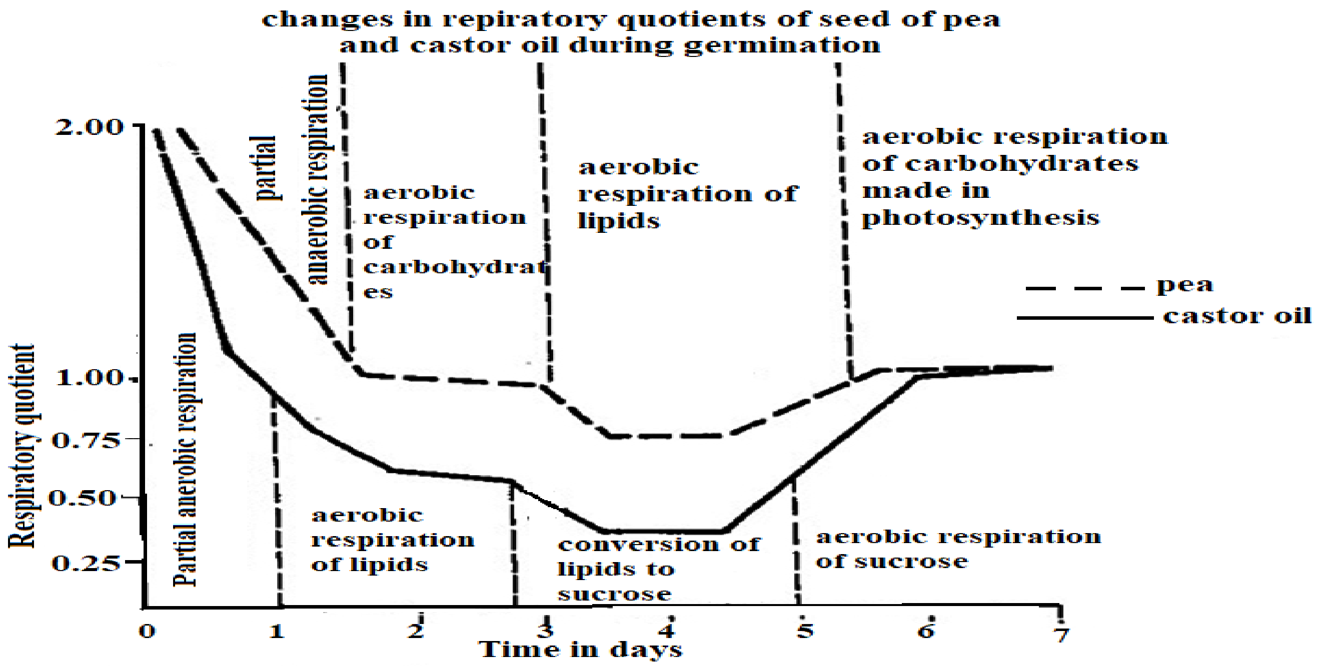
Carbon dioxide is released during respiration of seeds. The ratio of carbon dioxide given off to oxygen used in a given period of time is called the **respiratory quotient (RQ).** RQ indicates the type of substrate oxidized and whether aerobic respiration, anaerobic respiration or both taking place.

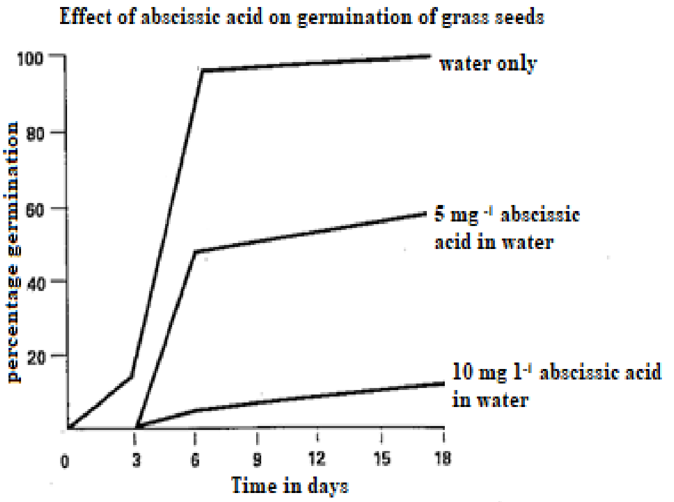
The testa of some seeds is relatively impermeable to oxygen so they respire anaerobically at the start of germination. Large bulky seeds such as broad beans have a small surface area to volume ratio which results in inadequate supply of oxygen to respiring cells and respire anaerobically. For these reasons the RQ can be greater than 1.0 during the first 24 to 48 hours of germination. The RG of seeds then falls to 0.7. This is because lipids are now respired aerobically. When a large quantity of lipids has been stored as in castor oil seeds, The RG at this stage may drop to as 0.35 owing to the conversion of lipids to sucrose

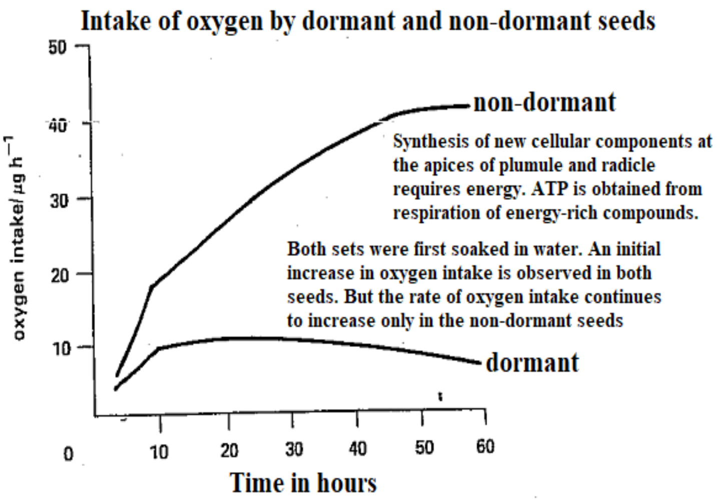
$C_{16}H_{40}O_6 + 11O_2 \rightarrow C_{12}H_{22}O_{11}$ (sucrose) $+ 4CO_2 + 9H_2O$

In carbohydrate-rich seed the RQ increase to 1.0 as aerobic respiration of sugars gets under way. The seedling eventually photosynthesize the RG becomes 1.0 in the mature plant.

$RQ = {}^{4}/_{11} = 0.3$







Emergence of the embryo root, the radicle. This is **positively geotropic** and will grow down and anchor the seed. Subsequently, the **embryo shoot**, the **plumule**, emerges and being negatively **geotropic** (and positively phototropic if above ground) will grow upwards.

There are two types of germination according to whether or not the cotyledons grow above ground or remain below it.

In **dicotyledons**, part of the shoot axis, or internode below the cotyledons (the **hypocotyl)** elongates, then the cotyledons are carried above ground. This is **epigeal** germination. When the internode just above the cotyledons (the **epicotyl)** elongates, then the cotyledons remain below ground. This is **hypogeal** germination.

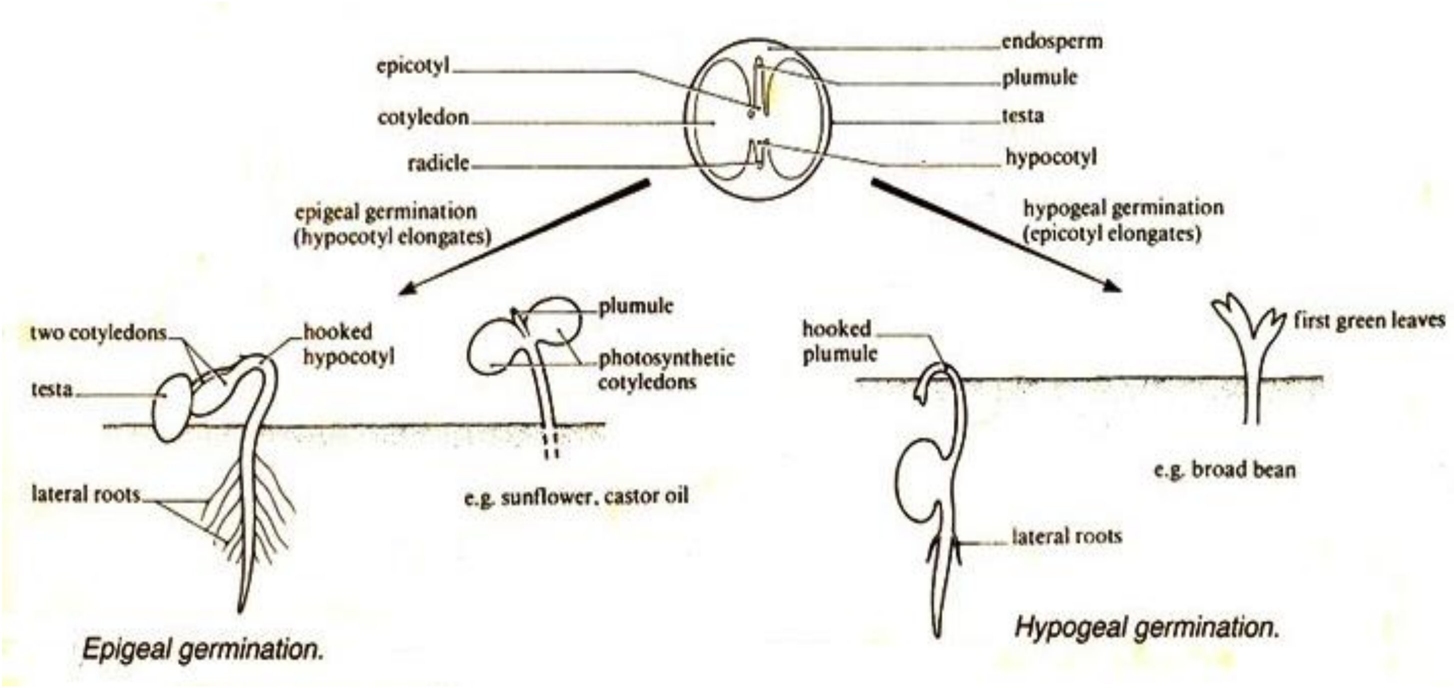
In **epigeal germination**, the hypocotyl remains hooked as it grows through the soil thus meeting the resistance of the soil rather than the delicate **plumule tip**, which is further protected by being enclosed by the **cotyledons.**

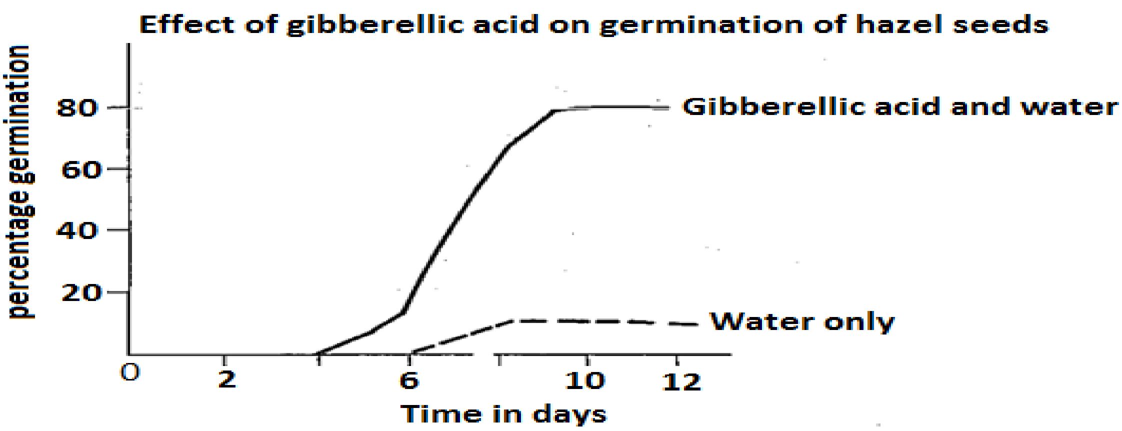
In hypogeal germination, the epicotyl is hooked, again protecting the **plumule tip**. In both cases the hooked structure immediately straightens on exposure to light, a phytochrome-controlled response.

In the grasses, which are monocotyledons, the **plumule** is protected by a sheath called the **coleoptile,** which is positively phototropic and negatively geotropic. The first leaf grows out through the coleoptile and unrolls in response to light.

On emerging into light a number of **phytochrome-controlled** responses rapidly occur in leaves, collectively known as **photomorphogenesis.** The overall effect is a change from etiolation to normal growth.

Expansion of the cotyledons or first true foliage leaves, and formation of chlorophyll starts the process of photosynthesis and net dry mass of the seedling starts to increase as it finally becomes independent of its food reserves.





PRIMARY GROWTH IN PLANTS

Growth in plants is confined to certain regions known as **meristems.**

A meristem is a group of cells which retain the ability to divide by mitosis, producing daughter cells which grow and form the rest of the plant body. The daughter cells form the permanent tissue, that is, cells which have lost the ability to divide.

Type of meristem	Location	Role	Effect
Apical	Root and shoot apex	Responsible for primary growth, giving rise to primary plant body	Increase in length
Lateral(cambium)	Laterally situated in older parts of the plant parallel with the long axis of organs, e.g the cork cambium(**phellogen**) and vascular cambium	Responsible for secondary growth. The vascular cambium gives rise to secondary vascular tissue, including wood(secondary xylem); the cork cambium gives rise to the periderm, which replaces the epidermis and includes cork	Increase in length
Intercalary	Between regions of permanent tissue, e.g. at nodes of many monocotyledons, such as bases of grass leaves	Allows growth in length in regions other than tips. This is useful if the tips are susceptible to damage. e.g. eating by herbivores, wave action.	Increase in length

Primary growth is the first form of growth to occur which results in elongation of the shoot and root system. In most monocotyledonous plants and herbaceous dicotyledons it is the only type of growth. It is a result of the activity of the apical, and sometimes intercalary, meristems.

Some plants continue with secondary growth from lateral meristems. This is most notable in shrubs and trees. Plants which lack extensive secondary growth are called **herbaceous plants** or herbs. A few herbaceous plants show restricted amounts of secondary thickening, as in the development of additional vascular bundles in *Helianthus* (sunflower).

Apical meristems and primary growth

A typical apical **meristem cell** is relatively small, cuboid, with a thin cellulose cell wall and dense cytoplasmic contents. It has a few small vacuoles and the cytoplasm contains small, undifferentiated plastids called **proplastids.** Meristematic cells are packed tightly together with no obvious air spaces between the cells.

The cells are called **initials.** When they divide by mitosis one daughter cell remains in the meristem while the other increases in size and differentiates to become part of the permanent plant body.

PRIMARY GROWTH OF THE SHOOT

In the apical shoot meristem, cell division starts from the shoot apex followed by cell enlargement and cell differentiation. Passing back from the dome-shaped apical meristem, the cells get progressively older.

Three basic types of meristematic tissue occur.

1. **protoderm**, which gives rise to the epidermis.
2. **Procambium** which gives rise to the vascular tissues, including pericycle, phloem, vascular cambium and xylem.
3. **Ground meristem** which produces the parenchyma ground tissues, which in the dicotyledons are the cortex and pith.

These meristematic types are produced by division of the meristematic cells (initials) in the apex.

In the Region cell of enlargement, the daughter cells produced by the **initials increase in size**, mainly by **osmotic uptake of water** into the cytoplasm and then into the vacuoles.

The **small vacuoles increase in size**, eventually fusing to form a **single large vacuole**. The **pressure potential** developed inside the cells **stretches their thin walls** and the orientation of **cellulose microfibrils** in the walls determines the final shape assumed by the cells.

As enlargement nears **completion**, many cells develop **additional thickening of the cell walls**, either of **cellulose or lignin,** depending on the type of cell being formed. This may restrict further expansion, but does not necessarily prevent it.

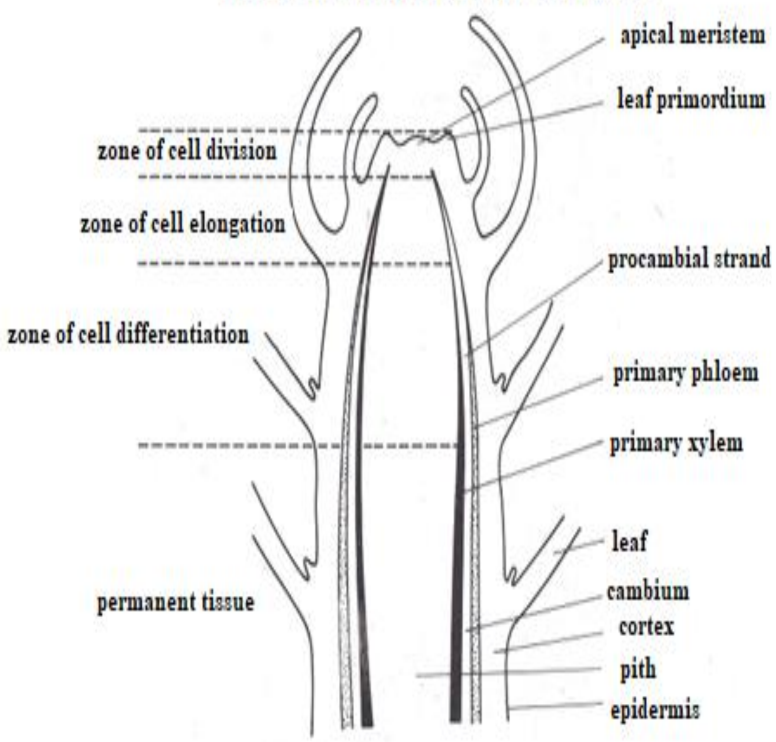
Collenchyma cells in the cortex, for example, can continue elongating while extra cellulose is laid down in columns on the inside of the original walls. Thus they can give support to the plant while still growing.

In contrast, developing **sclerenchyma** cells deposit thick layers of **lignin on their walls** and soon die. Thus their differentiation does not start until enlargement is virtually completed.

The first cells to differentiate in the procambium are those of the **protoxylem** to the inside, and **protophloem** to the outside. These are the parts of the primary xylem and phloem respectively, which form before elongation is complete.

The **protoxylem** typically has only annular or spiral thickenings of lignin on tracheids. Both protoxylem and protophloem elements **soon die** and generally get crushed and stretched to the point of collapse as growth continues around them. Their function is taken over by later-developing xylem and phloem in the zone of differentiation.

Tip of a young shoot showing early development



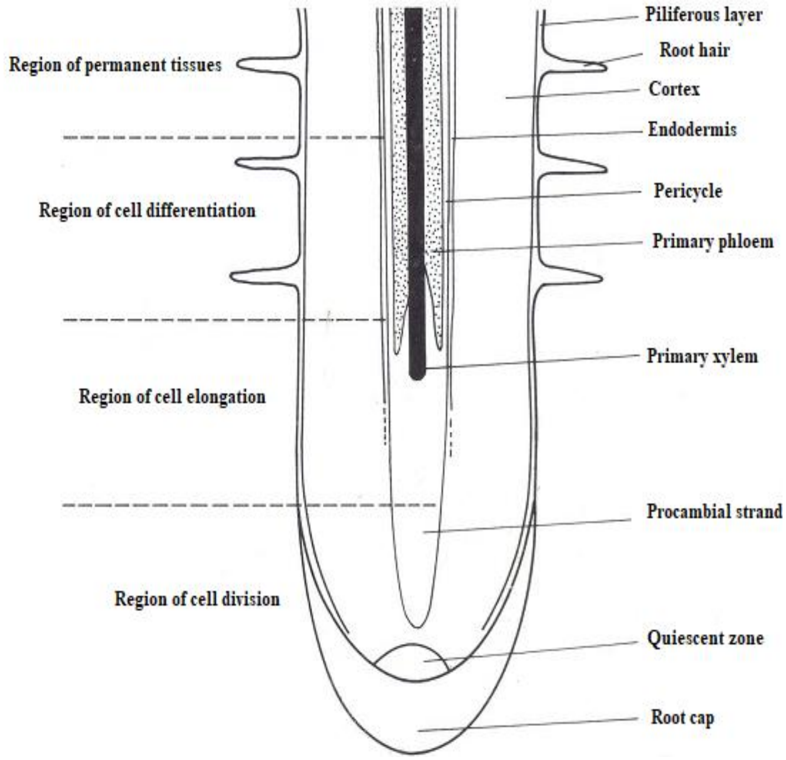
In this region each cell becomes fully **specialised** for its own particular function, according to its position in the organ with respect to other cells. The greatest changes occur in the **procambial strands**, which differentiate into **vascular bundles**. This involves **lignification** of the walls of **sclerenchyma fibres and xylem elements**, as well as development of the tubes characteristic of xylem vessels and phloem sieve tubes. Between the xylem and phloem there are cells which retain the **ability to divide**. They form the **vascular cambium,** which is responsible for secondary thickening.

Leaf primordia and lateral buds

Development of the shoot also includes growth of leaves and lateral buds.
Leaves arise as small swellings or ridges called **leaf primordia**.
The swellings contain groups of meristematic cells and appear at regular intervals, their sites of origin being called **nodes** and the regions between **internodes.** The pattern of leaf arrangement on the stem varies and is called **phyllotaxis.** Leaves may arise in whorls with two or more leaves at each node, or singly, either in two opposite ranks or in a spiral pattern. Leaves are arranged to **minimise** overlapping, and hence shading, when fully grown so that they form a mosaic.
The **primordia elongate rapidly**, so they soon enclose and protect the apical meristem, both physically and by the heat they generate in respiration. Later they grow and increase in area to form the blades.
Buds also develop in the axils between them and the stem. These are small groups of meristematic cells which normally remain dormant, but retain the capacity to divide and grow at a later stage. They form branches or specialised structures such as flowers and underground structures such as rhizomes and tubers.

PRIMARY GROWTH OF THE ROOT

At the tip of root apical meristem is a **quiescent zone,** a group of **initials** (meristematic cells) from which all other cells in the root can are found.
To the outside, the cells of the **root cap** are formed. These become large parenchyma cells which **protect** the apical meristem as the root grows through the soil.
They are constantly being worn away and replaced. They also have the important additional function of acting as g**ravity sensors**, since they contain large starch grains which act as **statoliths, sedimenting** to the bottoms of cells in response to gravity.
Behind the **quiescent centre**, **orderly rows** of cells take place and the meristematic regions i.e. **protoderm, ground meristem and procambium**, are formed.



Behind this zone, growth is mainly by cell enlargement. The zone of enlarging cells extends and increase in length forcing the root tip down through the soil.
Some cell differentiation begins in the zone of cell division, with the development of the first phloem sieve tube elements.
Further back in the zone of enlargement, the xylem vessels start to differentiate, also from the outside inwards (**exarch xylem**) in contrast to the stem (**endarch xylem).** The first-formed vessels are **protoxylem** vessels and they show the same pattern of lignification and ability to stretch as cells around them grow. Their role is taken over by **metaxylem**, which develops later and matures in the zone of differentiation after enlargement has ceased.
Further differentiation is completed by development of root hairs from the epidermis

SECONDARY GROWTH

Secondary growth is the growth which occurs after primary growth as a result of the activity of lateral meristems.

It results in an increase in **girth.** It is associated with deposition of large amounts of secondary xylem, called **wood**, which completely modifies the primary structure and is a characteristic feature of trees and shrubs.

Types of lateral meristem:

1. **vascular cambium** which gives rise to new vascular tissue
2. **Cork cambium or phellogen**, which arises later to replace the ruptured epidermis of the expanding plant body.

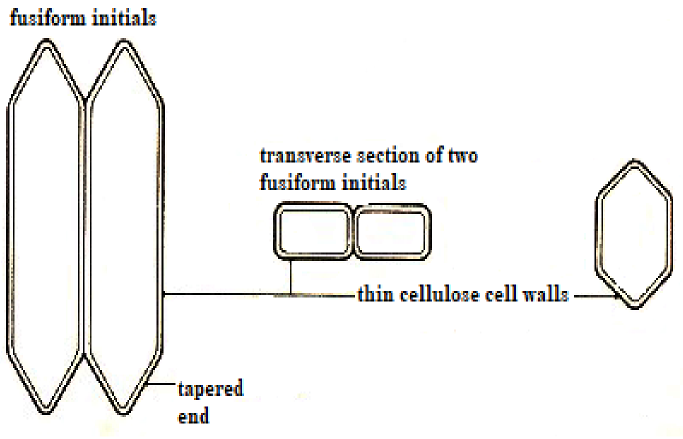
Vascular cambium

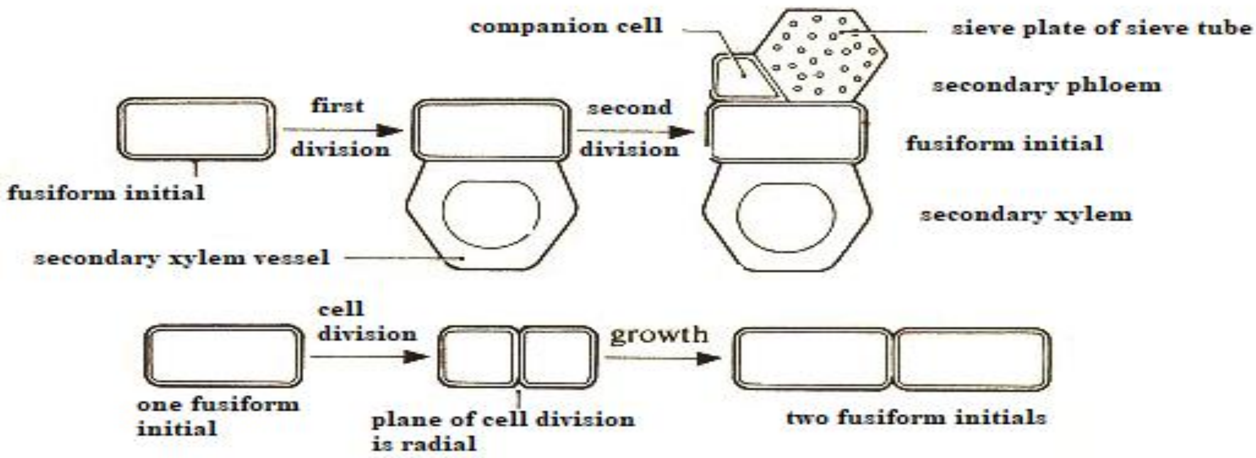
There are two types of cell in the vascular cambium, the ***fusiform initials*** and the ***ray initials***,

Fusiform initials are narrow, elongated cell and divide by mitosis to form secondary phloem to the outside or secondary xylem to the inside.

Secondary phloem contains sieve tube and companion cells, sclerenchyma *fibres* and *sclereids*, and parenchyma.

Ray initials are spherical and divide by mitosis to form parenchyma cells which accumulate to form rays between the neighboring xylem and phloem.

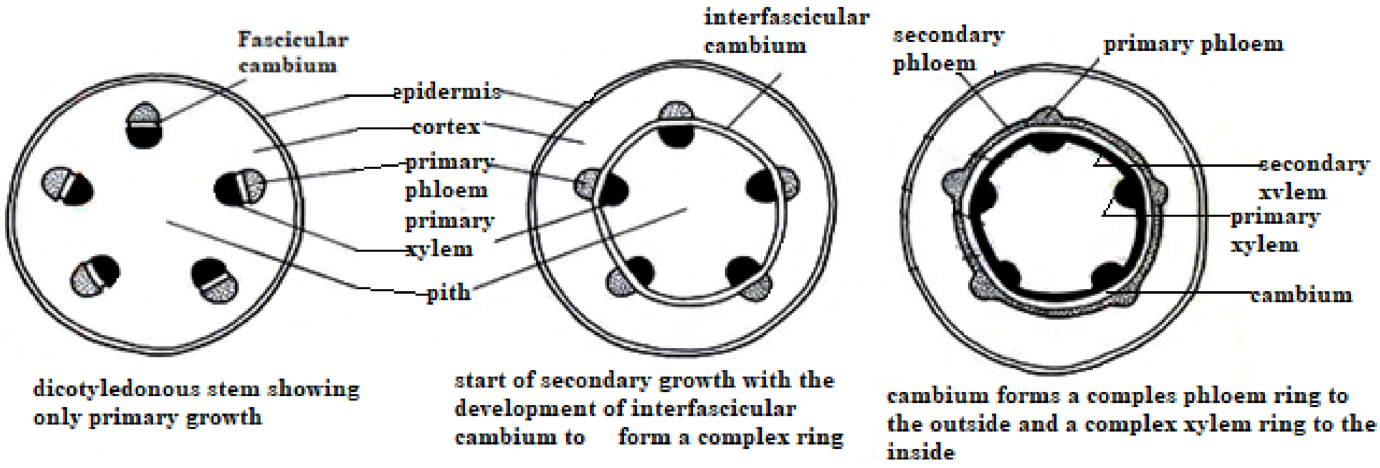




SECONDARY GROWTH IN WOODY DICOTYLEDON STEMS

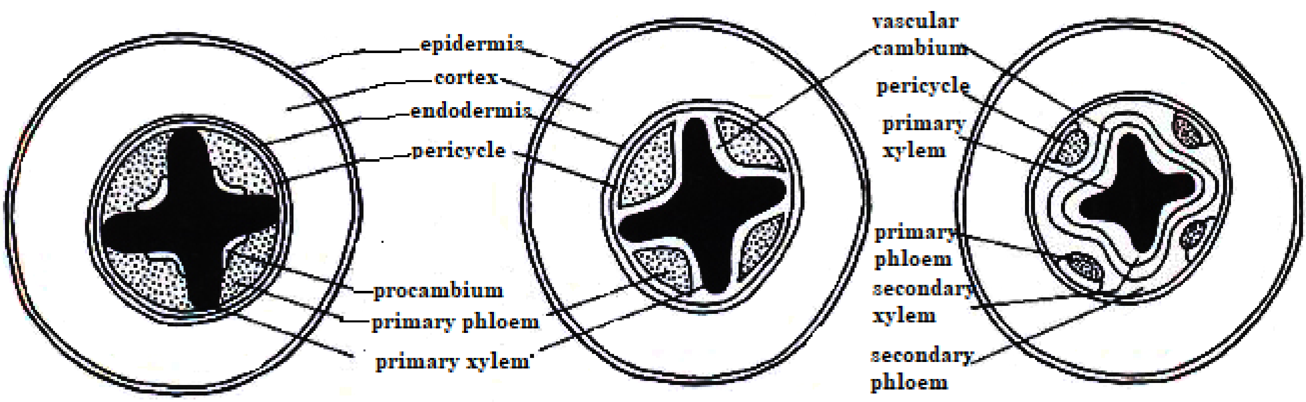
The vascular cambium is originally located between the primary xylem and primary phloem of the vascular bundles. It becomes active very soon after primary growth is complete. During secondary thickening fusiform initials produce large quantities of secondary xylem, and lesser quantities of secondary phloem, while the ray initials have produce rays of parenchyma. As the stem increases in thickness, so the circumference of the cambium layers' increase, radial divisions of the cambial cells occur.

Diagrams showing the early stages of secondary growth in a dicotyledonous stem



The **original ray initials** produce primary medullary rays which run all the way from pith to cortex. The rays maintain a living link between the pith and cortex. They transmit water and mineral salts from the xylem, and food substances from the phloem, radially across the stem. Also, gaseous exchange can occur by diffusion through intercellular spaces. The rays are also used for food storage, an important function during periods of dormancy, as in winter.

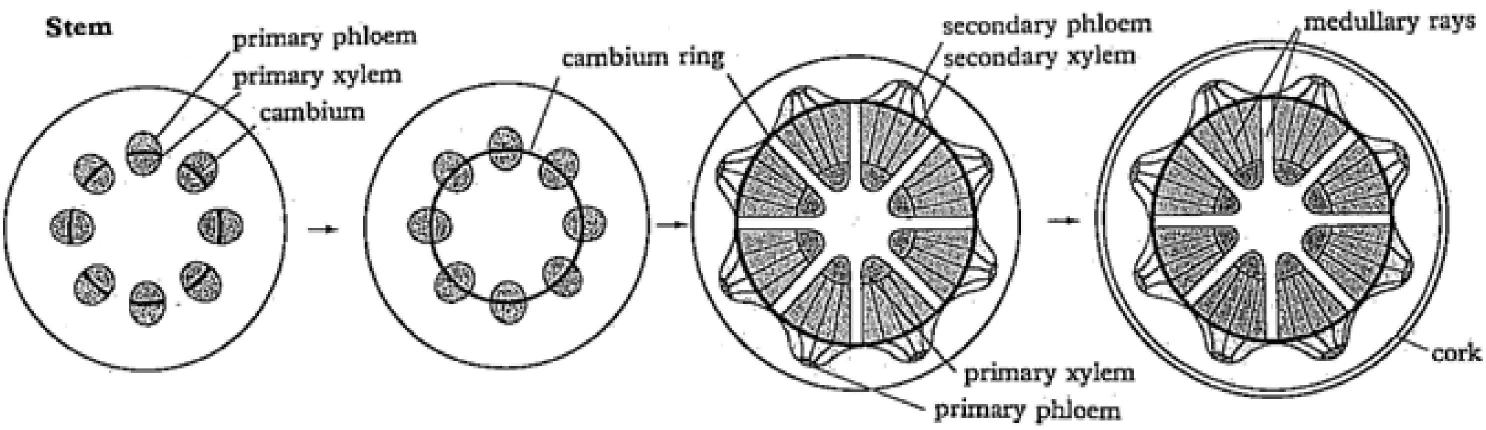
Diagrams showing the early stages of secondary growth in a dicotyledonous root

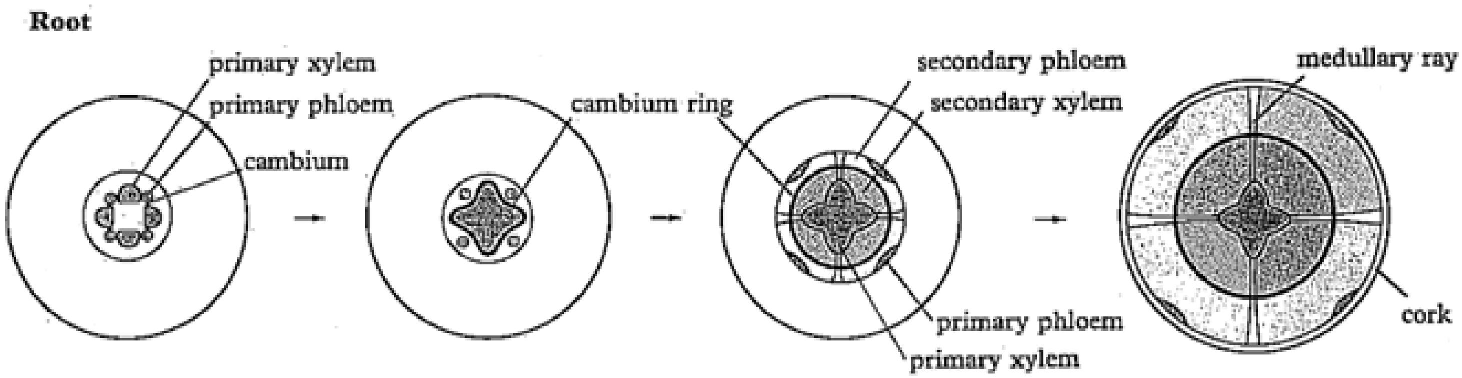


dicotyledonous root showing only primary growth

start of secondary growth with development of a ring of vascular cambium which merges with the pericycle

The cambium forms secondary phloem and xylem. The primary xylem remains in the centre but the primary phloem is crushed and remains with a little pericycle in small bundles

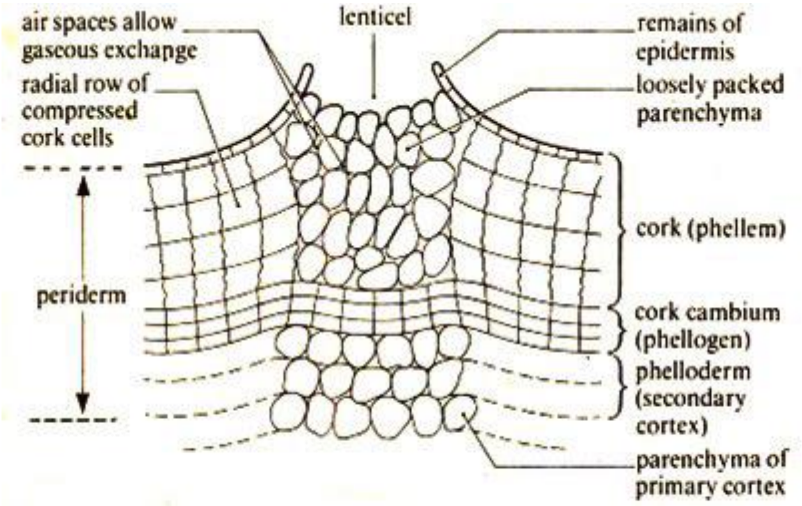




As a tree ages, the wood at the centres cease to serve a conducting function and become blocked with darkly staining deposits such as tannins. It is called **heartwood,** whereas the outer, wetter conducting wood is called **sapwood.**

Cork cambium: As the secondary xylem grows outwards, tissues outside it become increasingly compressed, as well as being stretched sideways by the increasing circumference. This affects the epidermis, cortex, primary phloem. The epidermis **rupture**s and replaced by cork as the result of the activity of a **second lateral meristem**, the **cork cambium** or **phellogen.** It arises immediately below the epidermis. **Cork (or phellem)** is produced to the outside of the cork cambium, while to the inside one or two layers of parenchyma are produced.

As the cork cells mature, their walls become **impregnated** with a fatty substance called **suberin** which is impermeable to water and gases. The cells gradually die and lose their living contents, becoming filled either with air or with **resin** or **tannins**.
The older, dead cork cells fit together around the stem, preventing desiccation, infection and mechanical injury. They become compressed as the stem increases in girth and may eventually be lost and replaced by **younger cells from beneath**. At random intervals, slit-like openings, or **lenticels**, develop in the cork which contain a mass of loosely packed, thin-walled dead cells, lacking *suberin*. They are produced by the cork cambium and have large intercellular air spaces allowing gaseous exchange.



Bark: Eventually a woody stem becomes covered with a layer commonly known as bark. Bark refers either to all the tissues outside the vascular system, or more strictly to those tissues outside the cork cambium. Peeling bark from a tree strips tissues down to the vascular cambium, a thin layer of cells which is easily ruptured.

It is usual for the cork cambium to be renewed each year as the girth of the stem increases. Often a cork cambium arises in the secondary phloem, in which case the bark will, over a number of years, build up a layered appearance due to alternating layers of secondary phloem and bark

GROWTH AND DEVELOPMENT IN HUMANS

Human growth and development is controlled centrally by the **hypothalamus** and **pituitary gland**. The hypothalamus controls the pituitary gland by secreting specific releasing and inhibitory factors which control the release of hormones from the pituitary gland. These in turn control other endocrine glands, which secrete hormones. In the case of growth and development these other glands include the thyroid gland, liver, adrenal cortex and gonads.

Anterior Pituitary gland secretes growth hormone Somatotrophin

Secretion of **human growth hormone (hGH)** is controlled by the combined effects of **growth hormone releasing hormone (GHRH**), also known as **somatocrinin,** and **growth hormone inhibitory hormone** (**GHIH**), also known as **somatostatin.** Human growth hormone has a direct effect on all parts of the body, but particularly on growth of the skeleton and skeletal muscles. It also has an indirect effect by stimulating the release of small protein hormones called **somatomedins** from the liver. Somatomedins, also known as **insulin-like growth factors** or IGFs because they resemble insulin in structure and in some aspects of function, mediate or regulate some of the effects of human growth hormone.

Humana growth hormone has direct effect to all body parts

- ✓ Increase growth rate of skeleton and skeletal muscle during childhood and adolescence
- ✓ Maintenance of muscle size and bone size in adults and promotion of tissue repair
- ✓ Increased rate of uptake of amino acids into cells
- ✓ Increases rate of protein synthesis
- ✓ Increases rate of cell growth and cell division
- ✓ Increases use of fat in respiration (instead of amino acids and glucose)
- ✓ Decreases uptake of glucose in respiration
- ✓ Increases level of glucose in blood

A deficiency of growth hormone results in **dwarfism**. Brain development and IQ are unaffected and the body parts stay in proportion. The victim develops much more slowly. If the problem is due to growth hormone alone, then affected individuals do mature sexually.

When over-production of human growth hormone occurs during childhood, when the bones are still capable of growth, the person becomes a **giant.** The usual cause is a tumour of the pituitary gland. In **adulthood,** bones continue to grow in thickness, together with an increased growth of the soft tissues. This results in a condition called **acromegaly**. The most distinctive feature of acromegaly is the enlarging of the hands, feet, skull, nose and jawbone.

Thyroid gland and growth: The thyroid gland secretes two hormones which influence growth and development, namely thyroxine **(T4)** and triiodothyronine **(T3).** They have similar effects. They stimulate protein synthesis important in stimulating growth of the skeleton.

Gonads (ovaries and male): Secrete sex hormones in response to signals from the pituitary gland and hypothalamus. The sex hormones are responsible for a fundamental change in growth and development and stimulate the development of secondary sexual characteristics.

Adrenal cortex: The adrenal cortex is the outer region of each of the two adrenal glands and secretes steroid hormones. In both sexes, these include small amounts of both female and male sex hormones, oestrogens and androgens respectively. The androgens contribute to the adolescent growth spurt and development of pubic hair and underarm hair in both boys and girls. In the adult male, there is very little production of sex hormones by the adrenal glands, but small amounts of oestrogens and androgens continue to be made in females. The androgens may contribute to sexual behaviour, including sexual drive.

GROWTH AND DEVELOPMENT IN INSECTS

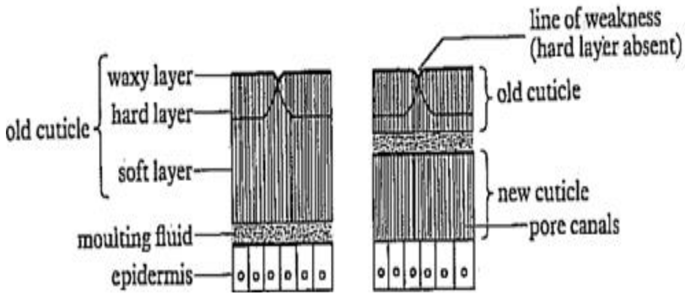
Insect metamorphosis: This is the series of changes which take place between larval and adult forms.

They usually involve a major reorganization of larval tissues.

Hemimetabolous (incomplete metamorphosis): The eggs hatch into nymphs which clearly resemble the adults except that they are smaller, lack wings and are sexually immature. There are a number of **nympha**l stages between which **moulting** occurs. Examples of hemimetabolous insects include locusts and cockroaches

Holometabolous (complete metamorphosis): The eggs hatch into larvae which differ considerably from the adults. Each larva undergoes a series of **moults** until it changes its appearance and becomes a dormant stage known as a pupa. After much reorganization of the tissues within the pupa, the adult (imago) emerges. Examples of holometabolous insects include moths, butterflies and flies.

The shedding process is known as **moulting** or **ecdysis**, and it takes place by the secretion of a moulting fluid immediately beneath the cuticle
This dissolves the soft inner pan oaf the cuticle, leaving only the hard outer part. Meanwhile the new cuticle, soft at first, is secreted by the epidermis. Protected from the enzymatic action of the moulting fluid by its protective surface, it is destined to become the hard cuticle of the next instar.



The cuticle is composed of chitin, a complex nitrogen-containing polysaccharide. Hardening of the outer part is achieved by the chitin being impregnated with tanned (hardened) proteins. Waterproofing of the cuticle is achieved by the deposition of a thin layer of wax at the surface.

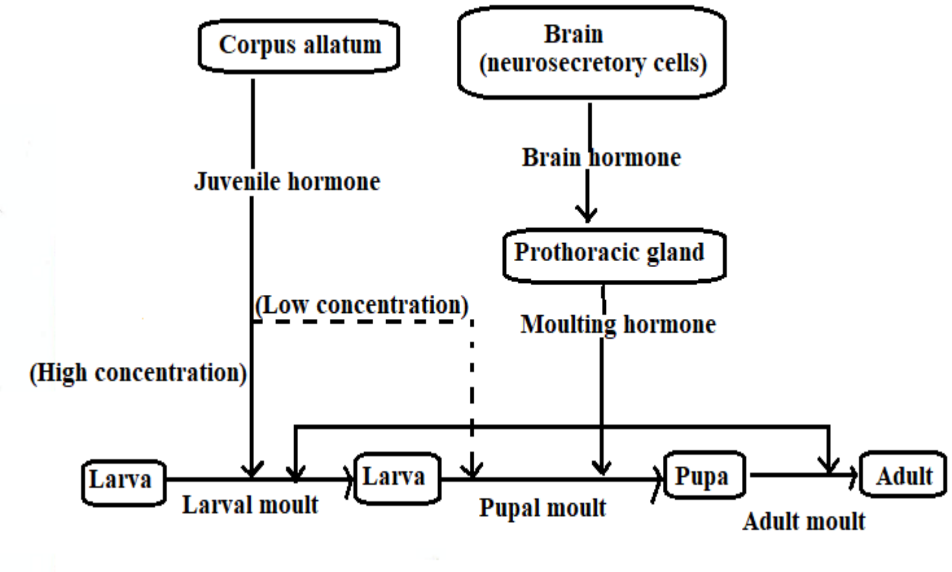
Control of insect metamorphosis

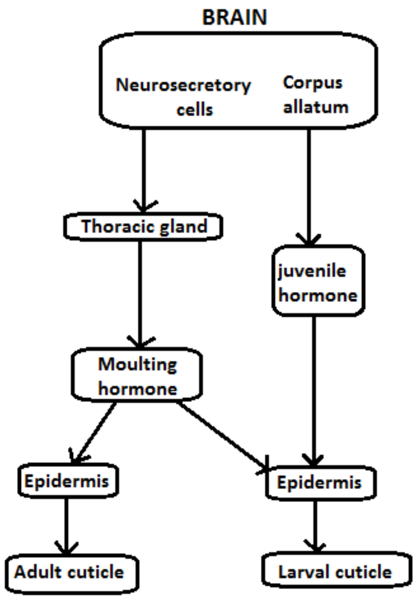
The control of insect metamorphosis involves **two main hormones**: **moulting hormone** (ecdysone) and **juvenile hormone** (***neotonin***).

Moulting hormone is produced by a gland in the first thoracic segment, called the **prothoracic gland**.

Juvenile hormone is produced by a region behind the brain known as the corpus **allatum.** The production of both hormones is controlled by neurosecretory cells in the brain.

All moults require moulting hormone. High juvenile hormone concentrations cause larval moults occur, insect remains as a larva. When Low concentrations of juvenile hormone are present a pupal moult occurs and the larva metamorphoses into a pupa. In the complete absence of juvenile hormone, the pupa metamorphoses into the imago (adult).

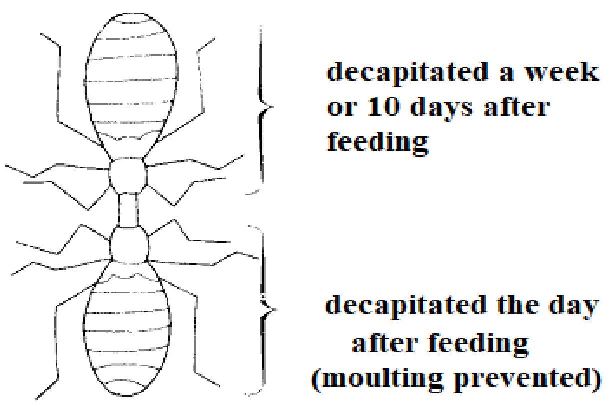




Experiment on *Rhodnius*

When a nymph of the blood-sucking bug ***Rhodnius*** is decapitated a day or two after gorging itself with blood, it continues to live for several months but moulting is prevented. When decapitation is delayed for a week or so after a meal, moulting takes place.

The hormone produced by the **head** during this period can be shown by a simple experiment. A ***Rhodnius*** nymph, decapitated the day after feeding (and thereby prevented from moulting), is connected by a capillary tube to another nymph decapitated a week after feeding. The capillary tube makes it possible for blood to pass freely from one nymph to the other. The result is that the first larva moults as usual.



The distension of the gut following a meal causes a hormone to be produced by **neurosecretory** cells in the brain. This flows into the thorax where it stimulates a gland to secrete a second hormone. This second secretion, a steroid, is known as the **moulting hormone**, and it brings about shedding of the cuticle and growth.

The **moulting** hormone switches on the genes needed to produce the enzymes necessary for growth. The **moulting** hormone certainly raises the metabolic rate, and increases the rate at which amino acids are built up into proteins in the growing tissues. Growth hormones exert their effects through the action of genes.

Metamorphosis in amphibians is controlled by **thyroxine** secreted by the thyroid gland in amphibians. Injecting thyroxine into a tadpole results in precocious metamorphosis; conversely, removing the thyroid from a tadpole prevents metamorphosis.

Metamorphosis is controlled by variations in the amount of thyroxine secreted by the gland, coupled with changes in the ability of the different tissues to respond to it.

DIAPAUSE

Amongst animals, a type of dormancy similar to that seen in plants is shown by insect is Known as **diapause,** it occurs at any stage in the life history: egg, larva, pupa or adult. In the dormant state, the creature may survive and remain viable for months or even years. Diapause is caused by the normal growth-promoting hormone not being produced in right amounts. These hormonal changes are related to day-length. As soon as the hours of daylight fall below a certain critical level, diapause sets in. The critical amount of daily light varies from insect to insect. In the cabbage white butterfly, it is about 12 hours: when the light falls below this level, the pupae enter diapause and do not resume development until the following spring. The light acts directly on the brain where, via the production of another substance or substances, it inhibits the growth-stimulating hormone. In some species the change to longer days is effective stimulus, but in many insects an obligatory period of cold is necessary before growth can be resumed. This is comparable to stratification in seeds and buds

GROWTH AND DEVELOPMENT IN VERTEBRATES

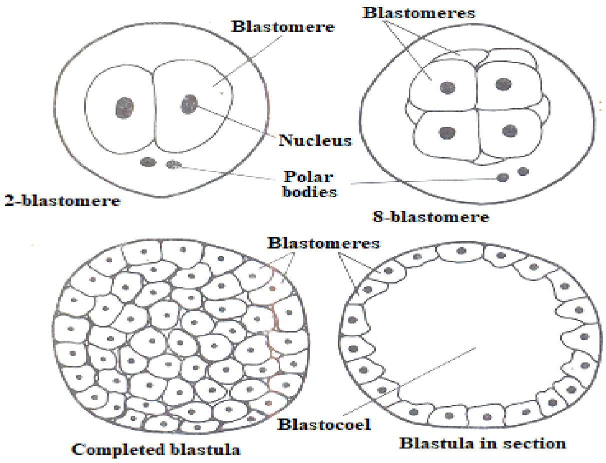
The development which follows fertilization in animals can be divided into three stages:

1. Cleavage: The mitotic division of the zygote to form a ball of identical cells.
2. Gastrulation: The arrangement of cells into definite layers.
3. Organogenesis: The differentiation of cells to form organs.

Cleavage: After fertilization, the nucleus of the zygote divides mitotically, followed by cleavage of the cytoplasm, a series of smaller and smaller cells called **blastomeres** are formed. These divisions continue, resulting in an embryonic structure called the blastula. The blastula has a cavity at the centre called a **blastocoel**. The extent of cleavage depends on how much yolk is present, as yolk inhibits cleavage. Where an animal has little or no yolk in the egg, e.g. *Amphioxus,* cleavage involves the whole cell and the **blastomeres** are small and of equal size. When much yolk is present, as in the frog, it is normally concentrated at the vegetal pole, with much less, if any, at the animal pole. Cleavage is inhibited at the vegetal pole and a few large cells called **macromeres** result. By contrast, cleavage occurs rapidly at the animal pole, producing many small cells called **micromeres.**

Gastrulation: Gastrulation involves the inpushing of one side of the ball of cells to produce a cavity called the **archenteron**, which later forms the gut. The structure as a whole is called the gastrula. At this stage the cells of the structure have their final fates determined, i.e. it is possible to predict their functions in the developed organism. These presumptive areas, as they are called, can be mapped with accuracy. During gastrulation the cells of these presumptive areas migrate to their correct positions. The blastocoel becomes obliterated and the cells of the gastrula become arranged into germ layers. There ar. three germ layers: The inner endoderm. The central mesoderm and outer ectoderm.

Cleavage in Amphioxus

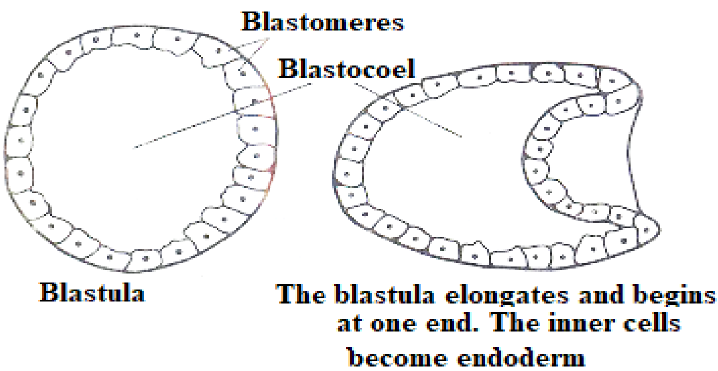


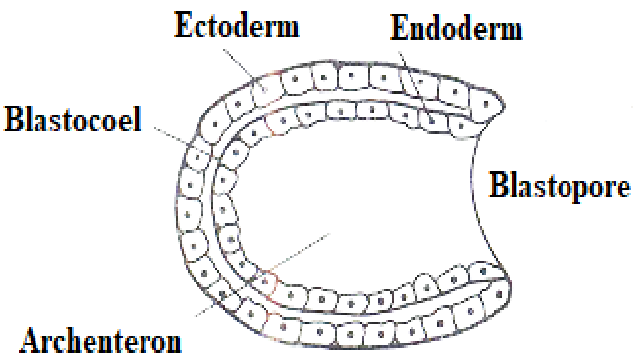
Germ layer	Tissue or organ formed during development
Ectoderm	Skin, scales, hair, feathers, jaws, nerves and central nervous system
Mesoderm	Striated muscle and smooth muscle, connective tissue(bone, cartilage, blood), heart, blood system, Reproductive system, eyes
Endoderm	Alimentary canal, Lining of gut, bladder and lungs, liver, pancreas and thyroid glands, Germinative epithelium

Organogenesis

The cells of the gastrula continue to divide and become differentiated The ectoderm folds inwards to become a neural tube which later develops into the nerve cord, the anterior part of which expands to form the brain. The embryo at this stage is called the neurula. The mesoderm forms a notochord which in vertebrates is replaced by the vertebral column. The gut increases in length and become folded and gradually all major organs such as the heart develop

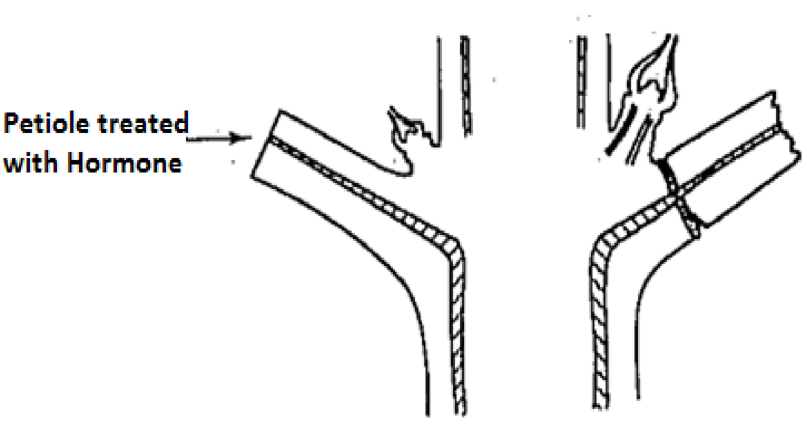
Stages in gastrulation





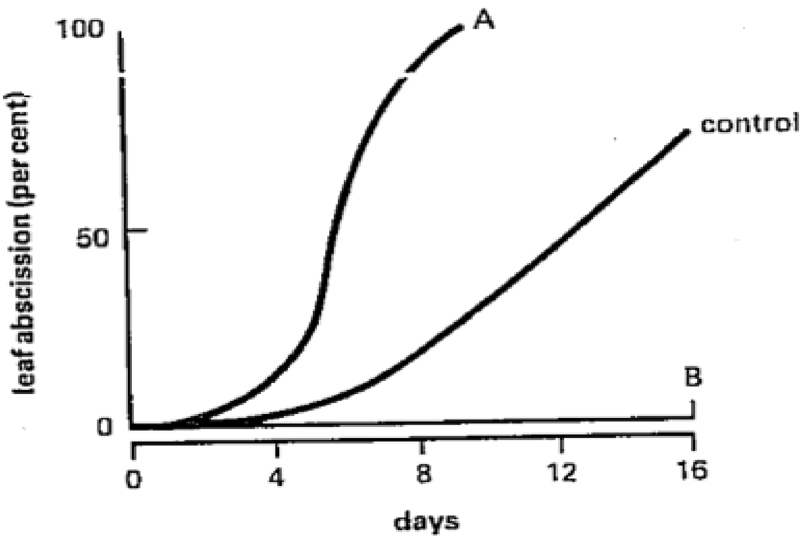
Completed gastrula. A two layered structure with a thin cavity of blastocoel which becomes obliterated in time

1. Two leaf blades were removed from a healthy intact plant. One of the petioles was left exposed and the other was treated with a hormone. Two weeks later longitudinal section through the petioles and stem was taken. The distribution of this section is shown in the figure below.



(a) (i)Describe three differences between the treated and untreated parts of the plant which are apparent from the figure.
(ii) Mark clearly with crosses the position of the two areas where actively dividing cells would be present.

(b)The effect of two hormones A and B on abscission of leaves in similar plants was measured. The results are shown in the graph.



(i) Compare the effects of the two hormones A and B on leaf abscission.

(ii) Explain the differences in the effects of the two hormones A and B on leaf abscission.

(iii) Which of the two hormones was applied to cut the petiole. Explain

(iv) Give the name of a hormone which could be hormone A