

GROWTH AND DEVELOPMENT.

Growth is an irreversible increase in size of an organism or its part measured as an increase in weight, volume, height or linear dimension.

Growth of multicellular organism is divided into three phase,

Cell division.

Is an increase in cell numbers as a result of mitosis and cell division.

Cell enlargement.

Is an irreversible increase in cell size as a result of the uptake of water or synthesis of living materials.

Cell differentiation.

This is specialization of cells where they develop specific structure to perform particular functions. Growth also includes the phase of development.

DEVELOPMENT.

Is the increase in the complexity of an organism which involves progressive changes that take place in organisms from conception or germination up to the period of full maturity. There are three phases of development,

Growth.

Is defined also as the irreversible and permanent increase in dry mass of an organism.

Differentiation.

Is the development of different cells, structures and functions.

morphogenesis.

The development of the overall form of the organs and hence the organism.

Some of the above events can still occur later in processes such as regeneration, repair and gametogenesis.

MEASUREMENT OF GROWTH.

Growth is estimated by measuring some parameters (variables) over a period of time. The parameter chosen depends on an organism whose growth is to be measured. It may be suitable to measure the weights of a mouse but the same method can not apply to the big tree such as the mango tree. Mass and length are the most common parameters often used but they mislead in some instances. Area or volume can give accurate indication of growth into in some cases are impracticable to measure. The measurements of mass has problems e.g. If an organ takes in a lot of food or water, the mass increases and yet such a temporary increase can not be considered as growth for this reason two types of mass are recognized

- i. **Fresh mass:** This is the mass of an organism under normal conditions. Its advantage is that, it is easy to measure and it does not damage the organism.
- ii. **Dry mass/ weight:** This is a form of mass that involves the removal of all water from an organism before weighing. It gives the most accurate results. Its disadvantage is that it is difficult to carry out and permanently destroys or kills the organism.

It is sometimes possible to measure; part of an organism e.g. thickness of a stem (girth of a tree). The length of a tail of a rat provided that, part grows in proportion with complete organs hence its increase in size reflects the growth of an organism (individual) as a whole.

Groups of organisms are sometimes used instead of an individual e.g. if the growth of pea plants was measured using dry mass it will be necessary to grow a large population of a plant. Growth is then estimated by removing a sample of about 10 plants every day drying and weighing them. The growth rate of peas can be found by repeating the process using different sets 10 pea plants at regular intervals.

The growth of a population of a single cell organism like yeast is measured by counting the number of cells in a known volume of medium (culture) in which yeast cells are grown. The samples containing the cells are mounted under a microscope called **a haemocytometer** where they are viewed and counted.

GROWTH PATTERNS

When any parameter of growth is measured against set intervals of time, growth curves are produced, in which increases in growth are plotted per unit time.

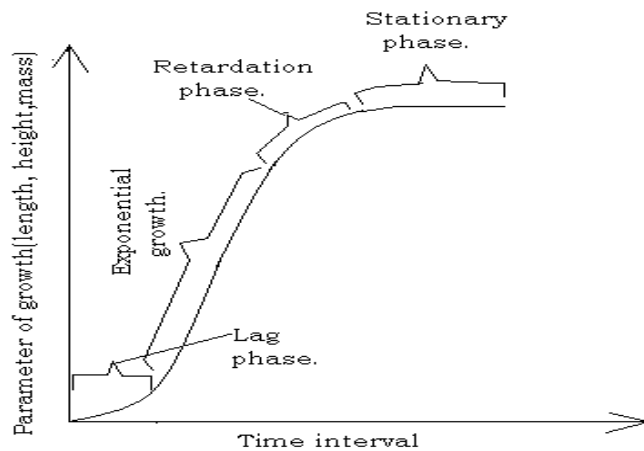
TYPES OF GROWTH CURVES.

- Absolute growth curve.
- Absolute growth rate curve.
- Relative growth rate curve.

(a) Absolute growth curve.

This is obtained by plotting parameters such as length, height, mass against time interval. It is also called actual growth curve (sigmoid/ S-shaped) curve. It shows the overall growth pattern and extent of growth. It can be applied to a population, or an organ of individual. In many cases the growth curve can be modified.

ABSOLUTE/ACTUAL GROWTH CURVE.



The sigmoid growth has four distinct phases,

- **A lag phase**, in which there is slow growth or no growth.
- **A log phase** of exponential growth in which growth is at its maximum. There is an increase in growth.
- **A linear phase/ Retardation phase**, in which the growth rate slows down and becomes limited by external factors, internal factors or both.
- **A stationary phase**, when the organism ceases to grow but maintains itself. The stationary phase is usually followed by senescence and eventually death.

For many population of organs or organisms, this curve is S-shaped at first (lag phases) because there are so few cells initially that even when they are dividing rapidly the actual increase in size is small.

At the number of cells become many, the size increases more rapidly because there are more, cells carrying out cell division. However, there's a limit to this rapid phase of growth. The limit is imposed by the genotype of an organism which specifies the max size or any external factor such as shortages of food. At this point, the growth rate decreased until it ceases. However the cells are still dividing but only at a rate which replaces those which are lost or damaged. The size of the organism therefore remains constant. Other cells carryout repairs.

(b) Absolute Growth rate.

This is drawn by plotting the increase in growth over successive periods of time against time. It is usually bell-shaped.

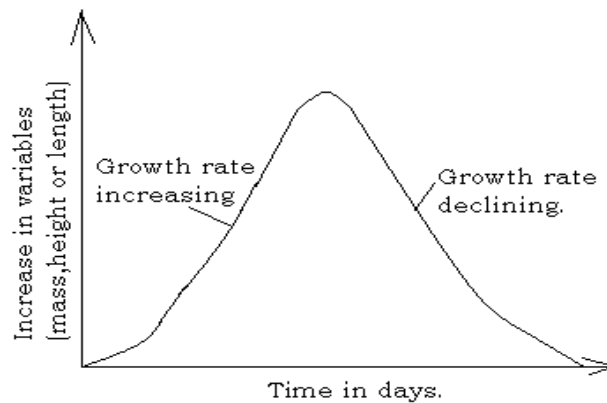
Growth rate curve measures the increase in growth during successive time intervals whereas Growth curve measures actual size of an organism at fixed time. It is observed that the rate of growth steadily increases and then falls or declines or decreases as the adult size is attained.

Absolute growth rate shows how the rate of growth changes with time. In particular it shows the period when growth is most rapid and corresponds to the steepest part of the absolute growth curve. The rate of growth decreases as the adult size is attained.

Consider the results below

Time in days	Height(mm)	Rate of growth
0	0	0
3	40	$40-0/3 = 13.3$
6	100	$100-40/3 = 20.0$
9	350	83.3
12	900	183.3
15	1600	233.3
18	2150	183.3
21	2400	83.3
24	2460	20.0
27	2500	13.3
30	2500	0.0

ABSOLUTE GROWTH RATE CURVE.



Study carefully the data presented below and uses it to answer the questions that follow.

Time per day	Height at the sort interval	Height at the end of time interval	Height increase in time interval	Rate of growth
0-0	0	0		
0-3	0	40		
3-6	40	100		
6-9	100	350		
9-12	350	900		

12-15	900	1600		
15-18	1600	2150		
18-21	2150	2400		
21-24	2400	2460		
22-27	2460	2500		
27-30	2500	2500		

QUESTIONS:

- (a) From the information provided in the table above,
- (i) Calculate the height increase in time interval and rate of growth,
 - (ii) Copy and complete the table above, include in your table the variables calculated in (i) above.
 - (iii) Plot suitable curves using the same axes showing rate of growth and actual growth against the time intervals.
- (b) Explain the shape of the curves.

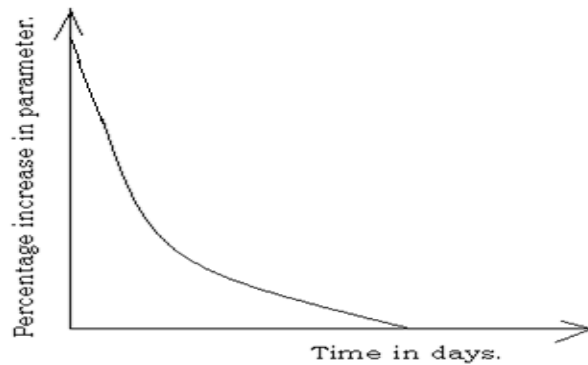
(c) Relative growth rate curve.

This is a curve which shows the changes in relative growth rate with time. It is obtained as increase in growth between successive time intervals expressed as percentage of growth that has already occurred and then plotted against time interval. The relative growth rate can be calculated from,

$$\frac{\text{Growth in given time period}}{\text{Measurement at start of time Period.}} \times 100 \quad \text{or} \quad \frac{\text{Absolute growth rate.}}{\text{Original measurements.}} \times 100$$

Relative growth rate gives the measure of efficiency of growth. This is the rate of growth relative to the size of the organism. For example if a 5 year old and a 10 years old human both grew 10 cm in height in one year, their absolute growth rate would be the same but the 5 years old would be growing relatively faster and have a greater relative growth rate.

RELATIVE GROWTH RATE CURVE.



EXAMPLE:

The following results were obtained from growth measurements of the height of a plant.

Day after planting.	Height in cm	Absolute Growth rate.	Relative Growth rate.
10	2	$2-0 = 2$	$2/2 \times 100 = 100$
20	7	$7-2 = 5$	$5/7 \times 100 = 71.4$
30	20	$20-7 = 13$	$13/20 \times 100 = 65$
40	40	$40-20 = 20$	$20/40 \times 100 = 50$
50	75	$75-40 = 35$	$35/75 \times 100 = 46.7$
60	110	$110-75 = 35$	$35/110 \times 100 = 31.1$
70	140	$140-110 = 30$	$30/140 \times 100 = 21.4$
80	150	$150-140 = 10$	$10/150 \times 100 = 6.7$
90	155	$155-150 = 5$	$5/155 \times 100 = 3.2$
100	160	$160-155 = 5$	$5/160 \times 100 = 3.1$

- (a) On the same axes plot graphs showing absolute growth curve, relative growth rate and absolute growth rate curve.
- (b) State the difference between absolute growth curve and absolute growth rate curve.
- (c) What is the significance of the relative growth rate?

MODIFICATIONS OF THE SIGMOID CURVES.

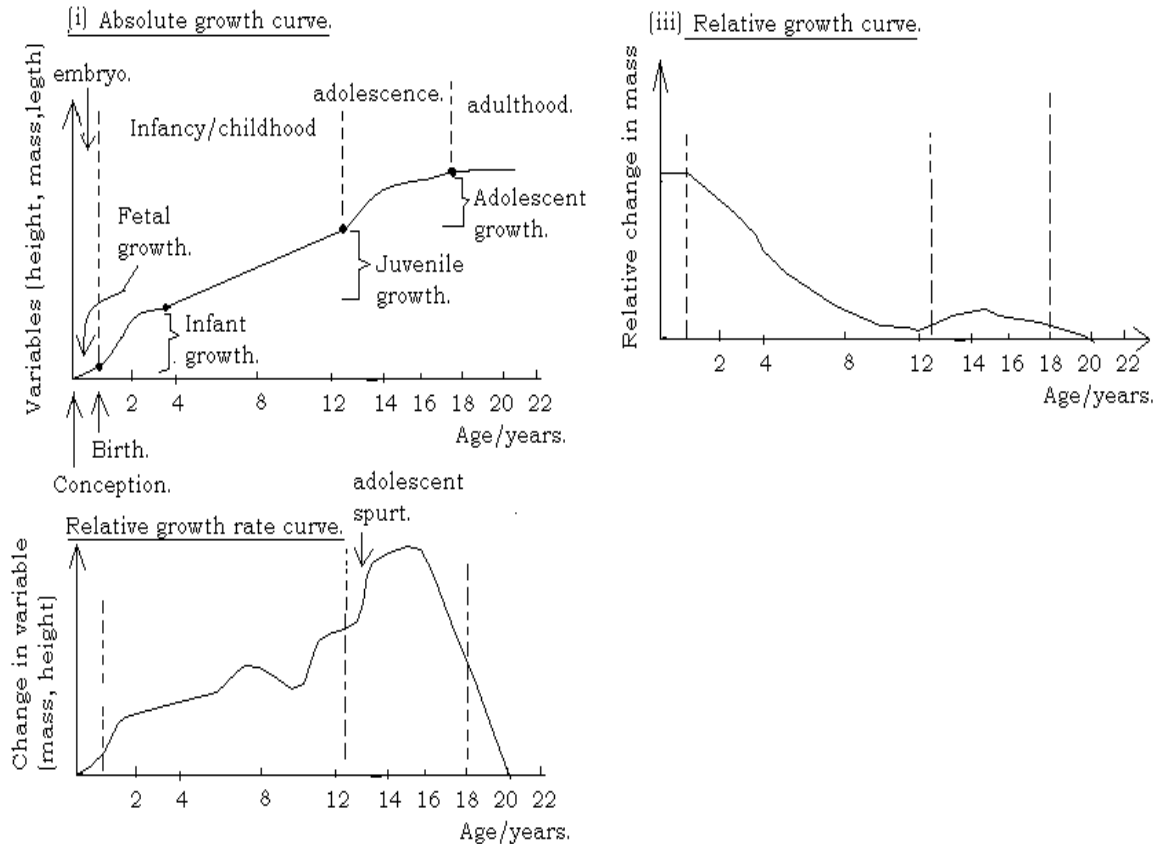
While the sigmoid curve forms the basis of most growth curves, it may be modified in different circumstances. These are,

(i) Human Growth curve.

In humans, there are two phases of rapid growth.

- During the early years of life i.e in an infancy state.
- During adolescent stage.

Between these 2 phases, there is a period of slow growth; the curve therefore resembles two sigmoid curves, one on top of the other humans.



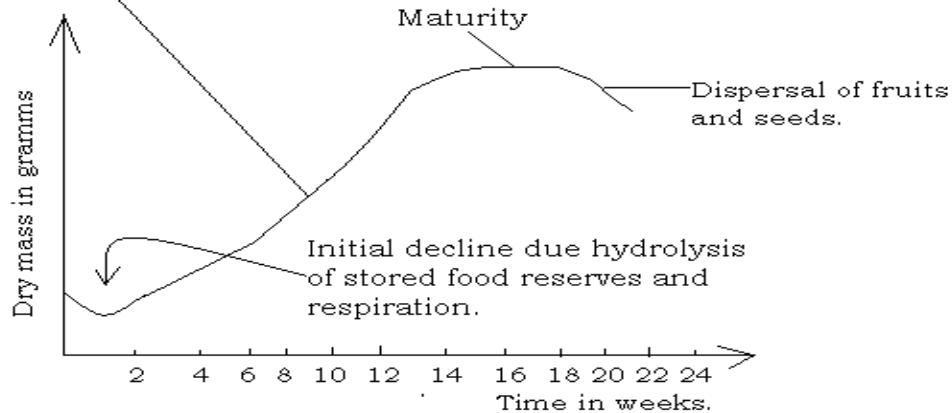
(ii) Annual Plant Growth curve.

The growth is typically sigmoid and characterised by an initial decrease in mass during the early stages of germination. This is due respiration and mobilization of food reserves in the seed in order to produce roots and leaves. Alpha amylase catalyze break down of starch to maltose and then to glucose, lipase breaks down lipids to fatty acids and glycerol, protease breaks down proteins to aminoacids. The soluble products, glucose, amino acids, fatty acids and glycerol are transported to the embryo, where they are utilized for the formation of roots and leaves. Once the leaves begin to photosynthesize, fruits develop, the rate of growth is rapid and dry mass increase rapidly. However, due to senescence, the leaves and fruits begin to fall off at the end of the growing season. Dry mass decline. When there is a natural limit like in annual plants, no growth occurs and the plants are said to show limited growth. At this stage the growth rates level off and may decline rapidly prior to the death of the organism. Organisms with a limited growth normally grow up to a predetermined size within the normal range of organisms till when

growth is complete. Growth of organs of annual plants such as the fruits and seeds also show a pattern of limited growth. Once the fruit has reached full size, it does not grow further but only plays an important role in dispersal.

ANNUAL PLANT GROWTH CURVE.

Green leaves appear, rate of photosynthesis exceeds that of respiration.



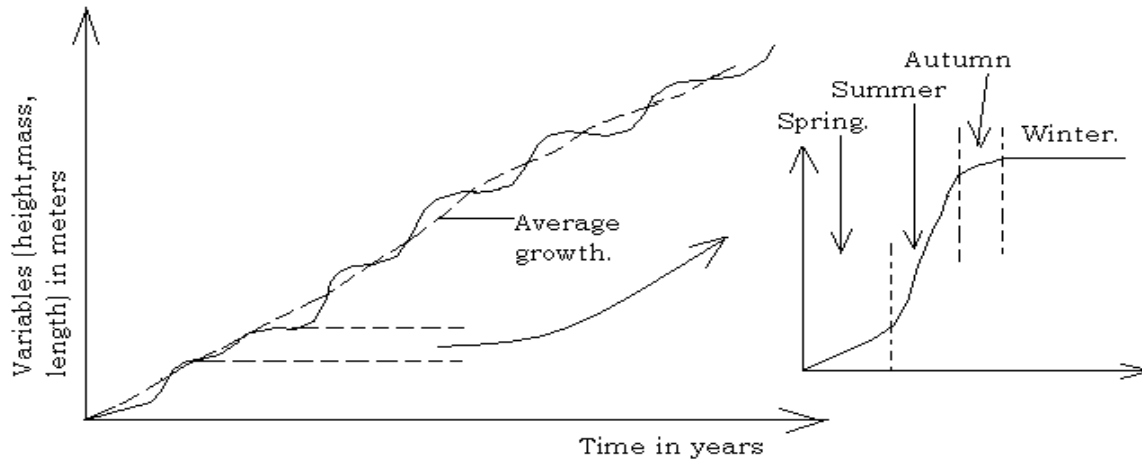
PERENIAL PLANT GROWTH CURVE

The growth pattern is an annual series of sigmoid growth curve i.e one sigmoid curve represent one year's growth.

During spring when the temperature and light intensity are relatively low. There is less photosynthesis and low growth rate but rate of photosynthesis increases and growth is rapid during summer when light intensity is high. The falling temperatures and lowering of light intensity in autumn again reduces the rate of photosynthesis hence slow growth.

During winter in temperate regions, there is no growth in the deciduous plants and so the curve flattens out (levels off). Following the next spring the process is repeated. The overall shape of these normal sigmoid curves, it is a sigmoid curve except that many perennial plants show unlimited growth, i.e they grow continuously through out their lives and the curve never flattens (levels off). Other examples of unlimited growth include growth of obelia, fungi and algae etc.

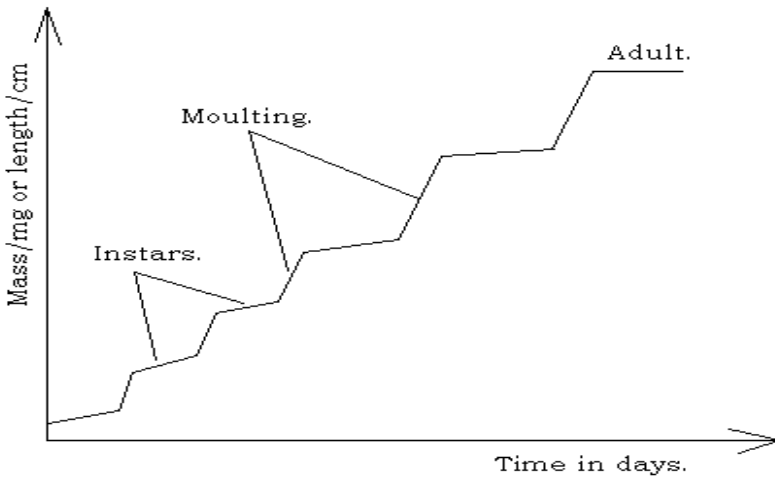
PERENIAL PLANT GROWTH CURVE.



ARTHROPODS GROWTH CURVE.

A different growth curve is exhibited by arthropods. This is because the exoskeletons of insects are hard and limit growth. During growth periods in insects, moulting occurs between each stage and increase in length is confined to brief periods before the new exoskeleton hardens. Moulting causes sudden increase in mass because growth can only occur during moulting. During this time the insect takes in as much water as possible in order to expand the exoskeleton. Therefore measuring a fresh mass as growth would give a different curve (growth pattern). Such type of growth pattern exhibited by arthropods is referred to as intermittent growth, but if a dry mass is measured a normal sigmoid curve is obtained.

INTERMITTENT GROWTH CURVE IN INSECTS.

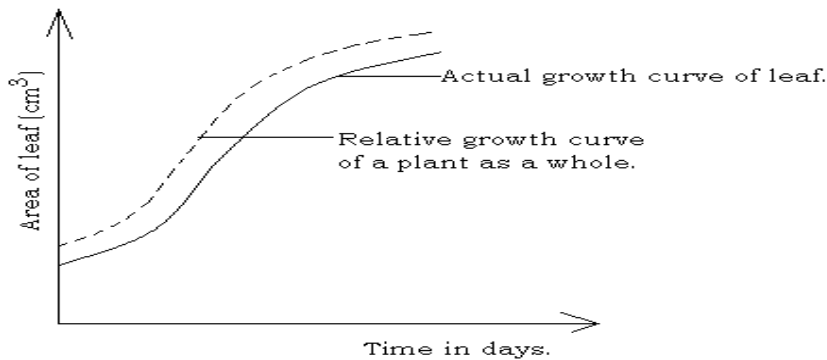


ISOMETRIC AND ALLOMETRIC GROWTH CURVES.

ISOMETRIC GROWTH CURVE.

Is where the organ grows at the same rate as the growth of the whole body of an organism and their growth curve is sigmoid e.g. the leaves of plants exhibit isometric growth. For example the leaves of the cucumber. In isometric growth, proportions of the plant remain the same. That is the change in size of the organism is not accompanied by change in shape of the organism. Isometric growth is also exhibited b insects such as locusts and by fish.

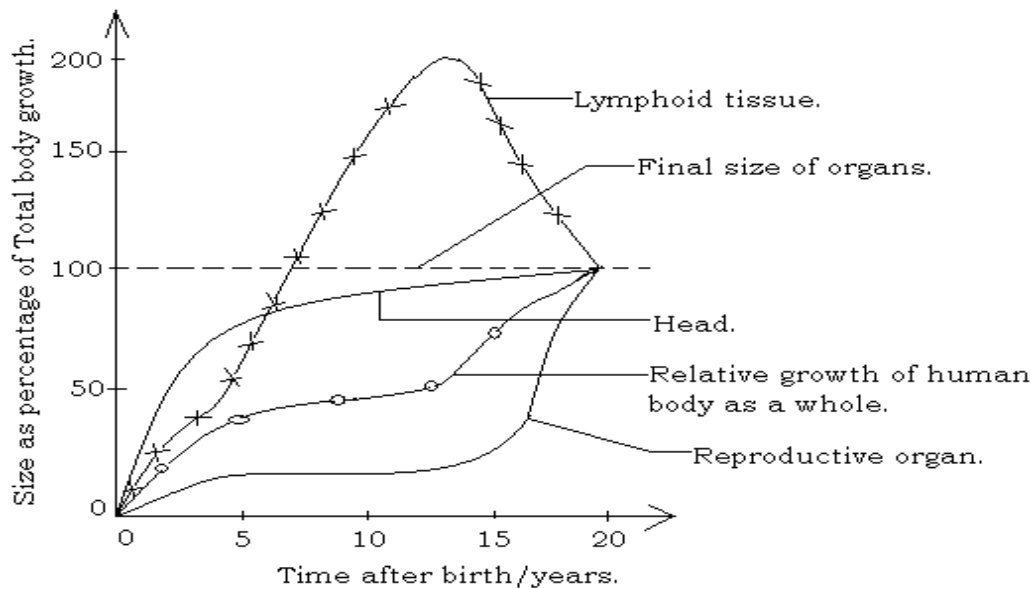
ISOMETRIC GROWTH/CURVE SHOWN BY THE LEAF OF A CUCUMBER.



ALLOMETRIC GROWTH CURVE

Is where the organ does not grow at the same rate with the growth rate of the entire organism. This produces a change in size of the organism which produces a change in the shape of the organism. For example, Human organs.

ALLOMETRIC CURVES SHOWING RELATIVE GROWTH RATES OF LYMPHOID TISSUE, HEAD AND REPRODUCTIVE ORGANS IN THE HUMAN BODY.



DESCRIPTION AND EXPLANATION OF THE ALLOMETRIC CURVES.

Brain (head) grows very fast during the first five years and then grows gradually reaching maturity size at 15 years; in order to effectively coordinate the body's activity.

Lymphoid tissue(Thymus gland) grows rapidly up to 12 years; reaches maturity size at 7 years; it doubles the maturity size by 12 years. It reduces to maturity size by 20 years. The lymphoid tissue produces white blood cells to fight against infections in early life.

Thus providing the young organism with natural immunity since the risk of infection is higher at infancy since their immunity is not yet fully developed. Lymphoid tissue is therefore involved in the immune system development at early age and by 20 years; the immune system has well developed.

Reproductive organs grow slowly during the first 13 years; followed by rapid growth up to maturity size and 20 years; this is when it begins to effectively function at puberty. The whole body grows rapidly up to 7 years; then grows rapidly up to 7 years then grows gradually up to about 11 years and then very fast from 11 years to 20 years. This is because of tissue formation at early years and rapid elongation of limbs in the later years.

In animals, organs exhibit allometric growth. Lymph tissues which produces white blood cells when the rate of disease is greater and immunity has not yet been acquired. By adult life, the mass of lymph tissue is less than half what it was in early adolescent. The reproductive organ grows at sexual maturity during puberty. The head grows rapidly in early years, slows down steadily until the final size of adolescent.

GROWTH AND DEVELOPMENT IN PLANTS.

SEED GERMINATION:

Is the onset of the growth and development of the embryo, usually after a period of dormancy. Germination required water, oxygen, and temperature within a certain range normally (35°C -40 °C). In some seeds light is also required. These are referred to as the favourable conditions for germination.

CONDITONS NECESSARY FOR SEED GERMINATION

(i) Water.

The initial up take of water by the dehydrated seed is known as imbibition. It is caused by adsorption of water by the molecule of the cell and as a result, the seed begins to swell as the water moves into the cell. Water softens the seed coat. It is used in the process of vacuolation of cells. Water also activates the release of the hormone gibberellin from the embryo that activates the synthesis of hydrolytic enzymes. Medium for most metabolic activities, soluble products of hydrolysis are transported dissolved in water. When seeds imbibe water, the seed coat are softened, the seeds swell opening up many air channels on the seed.

(ii) Optimum temperature

This varies from species to species of seeds but it ranges from 25-30 °C because temperature controls the enzyme related metabolic processes of the seeds.

(iii) Oxygen.

Seed differ in their requirements for oxygen, some seed like the aquatic plants and others like rice seeds germinate under water as they need less oxygen. While others like those of plant germinate only in soil where there's enough oxygen. Oxygen is used in respiration of the foods in the seeds in order to provide energy necessary for the process. Metabolic activities start again. They are anaerobic initially but become aerobic sometime after.

PHYSIOLOGY OF GERMINATION.

Under favourable conditions for germination in the soil, seed takes up water rapidly initially by imbibition and later by osmosis by the roots, this water causes the seed coat to swell and it ruptures the testa (seed coat). Water is also needed for vacuolation of cells and transport during germination. At the same time, the water activates the embryo to secrete the hormone gibberellin which catalyses the synthesis of the hydrolytic enzymes such as amylase, lipase and protease. In the seed these enzymes hydrolyse insoluble food storage materials into soluble substances in the following ways,

- Amylase catalyses breakdown of starch into soluble maltose and then to glucose. The glucose is then converted to sucrose.
- Protease (peptidase) catalyses the break down of proteins into polypeptides and aminoacids.
- Lipase catalyses the breakdown of lipids into fatty acids and glycerols.

Sucrose/glucose, amino acids (amides), fatty acids and glycerol are soluble products and are transported into embryo. At the growing apices of the embryo, sucrose is used to synthesize cellulose, pectic compounds which are the main compound or components of plant cells, some sucrose is respired to provide energy for growth.

At the growing points of the plumule and the radicals the amides are deaminated and the amino acids formed are used to synthesize structural proteins and enzymes.

Fatty acids may be oxidized to release energy or converted to sucrose for transport and utilized in synthesis of cell membranes. Glycerol which is only a small part of the lipid molecule is converted to sucrose. This sucrose can be respired or used to form structural components in the cells of the plant.

Early growth results in the plumule (shoot) and the radicle (embryonic root) growing rapidly. The radicle grows down wards while the plumule grows upwards. The cotyledons may be carried out of the surface of the soil in **epigeal germination**, in which they form the first photosynthetic structures because they are green with chlorophyll. In some plants, the cotyledons remain below the ground in hypogeal germination.

TYPES OF GERMINATION

There are 2 types of germination according to whether or not the cotyledon grows above the ground or remain below.

- i. Epigeal germination.
- ii. Hypogeal germination.

Epigeal germination.

In epigeal germination, the hypocotyls elongates more than epicotyl. The radicle grows downwards and the plumule upwards. The cotyledons (embryonic leaves) are carried up and out of the soil by this growth. Cotyledons form the first photosynthetic structure e.g. castor oil, beans, sun flower.

Hypogeal germination

In hypogeal germination, the epicotyl's elongates more than hypocotyls, the cotyledons remain below the soil surface e.g. in broad maize, wheat etc.

DIFFERENCE BETWEEN EPIGEAL AND HYPOGEAL GERMINATION

<i>Epigeal</i>	<i>Hypogeal</i>
<ul style="list-style-type: none"> - Hypocotyls grow faster than epicotyls. - Cotyledons are brought above the ground. - Cotyledons act as first green leaves for photosynthesis 	<ul style="list-style-type: none"> - Epicotyls grow faster than hypocotyls. - Cotyledons remain below the ground. - Cotyledons have no part in photosynthesis.

CHANGES THAT OCCUR AT THE TIME OF SEED FORMATION.

- (i) At the time of seed formation, further development of the embryo stops and it becomes dormant.
- (ii) Seed sheds off most of its water.
- (iii) All metabolic activities come to stand still and the respiration rate becomes low.
- (iv) Seed coat becomes impermeable to oxygen and moisture and seed coat hardens.

NOTE:

The embryo inside is alive but shows no sign of life. It is said to be in a state of suspended animation. It remains dormant till the onset of favorable conditions. All this period is referred to as the dormancy period.

SEED DORMANCY

It is a state of the seed such that although it is viable (alive) it will not germinate under conditions favourable for germination e.g. light, H₂O, O₂ and temperature.

CAUSES OF SEED DORMANCY AND HOW THEY ARE PREVENTED.

- Presence of germination inhibitors e.g. abscissic acid, it is broken by use of germination promoters such as the gibberellins.
- Immature embryo, broken by providing *after ripening periods*. This is internal physiological changes that occur in some seeds before they can germinate
- Hard seed coat, broken by scraping testa/scarification, soaking for a brief moment in concentrated sulphuric acid.
- Short/long day lengths, broken by exposing the seeds to required day length
- Lack of light, can be broken by exposing the seeds to light.
- Lack of a period of cold treatment/chilling/stratification, broken by providing required temperatures.

ADVANTAGES OF SEED DORMANCY

- (i) It allows for seed dispersal.
- (ii) Seeds are able to survive unfavourable conditions like the drought.
- (iii) It prevents seeds from germinating from the pod.
- (iv) The low metabolic rates enables the seeds to stay for long periods

DISADVANTAGES OF SEED DORMANCY

- (i) prolonged storage leads to decreased food reserves.
- (ii) It results in delay of transfer of genes to the next generations, leading to delayed colonization of habitat.
- (iii) It increases the chances of seed destruction by the pest because of prolonged stay in dormant phase.

EFFECT OF LIGHT ON SEED GERMINATION

Certain seeds like lettuce and tobacco germinate only when they are exposed to light. They are light sensitive due to presence of the light receptor pigment known as phytochromes.

This chemical is a blue-green pigment protein in nature and it exist in 2 forms

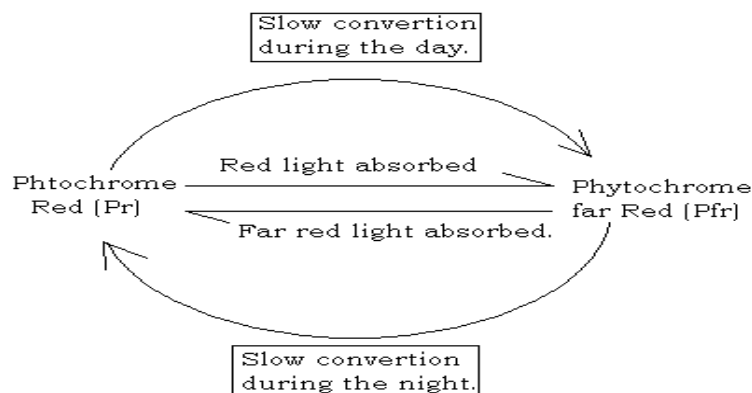
(i) Phytochrome red (P_{fr}) or P_{730} .

(ii) Phytochrome red, Pr or P_{660} .

Both forms are interconvertible as any of them absorbs light. When any of them absorbs light they are converted to any other form within seconds, P_{fr} (P_{730}) absorbs far red light in the 730nm range and converted to phytochrome red (Pr). Under adequate light, phytochrome red absorbs red light and converted to phytochrome far red (P_{fr}). P_{fr} is physiologically more active than phytochrome red Pr (p600).

The P_{fr} can induce germination in seed, Pr (P_{660}) absorbs red light and converted to P_{fr} (P_{730}), which promotes germination of seeds. P_{fr} absorbs far red light and converted to Pr, this inhibits germination of seeds and it is an inactive form. During the day, Pr is converted to P_{fr} and during the night phytochrome far red is slowly converted to Pr.

THE INTER-CONVERSION OF PHYTOCHROME FAR RED (P_{fr}) AND RED (Pr).



NOTE: Seeds germinate when exposed to red light of visible spectrum 600nm. Seeds remain dormant when exposed to far red light 730nm.

Incase brief exposure of both kinds of light are given, the kind of light given last determines the kind of response.

When water soaked light sensitive lettuce seeds were exposed to alternately red and far red lights in close succession it produces the following;

Sequence of Radiation	Last radiation given	Effect of germination.
R	red	Germination
R+FR	far red	No germination.
R + FR + R	far red	Germination.
R+FR + R + FR	far red	No germination.

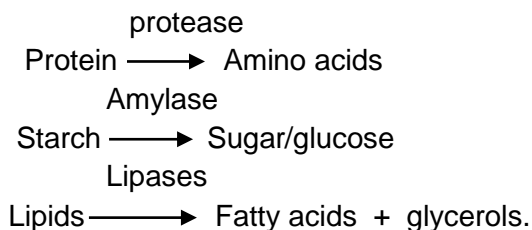
They germinate when exposed to red light due to the absorption of light by Pr and its conversion to Pfr. Pfr is chemically active form and promotes germination of some seeds. In the visible spectrum of sun light, red light is predominant and so there is more of Pfr formed in the plant and this promotes germination. At night Pfr is slowly converted to Pr and so there is more Pr in the plant. This inhibits germination and instead promotes seed dormancy. Phytochrome not only controls seed germination but also involve in changes like growth, lengthening, and branching of stems, etiolation leaf growth, chloroplast development and flowering.

MOBILISATION OF FOOD RESERVES DURING SEED GERMIANTION

Food material is stored in form of carbohydrates, proteins and lipids in the seed. In some it is stored in endosperm while others store in the cotyledon of the embryo.

During seed germination as the seed imbibes the water embryo becomes activated and secretes gibberellins. The activity begins both at the storage centres such as endosperms and cotyledons where there are food reserves and at the embryo. The sequences of events occuring during germination are;

- (i) Imbibition of water by seeds.
- (ii) Activation of embryo which secretes gibberellins.
- (iii) Diffusion of gibberellins to aleuron layer.
- (iv) Synthesis of ∞ amylase and other enzymes into aleuron layer.
- (v) Diffusion of hydrolyzing enzymes from a leuron layer to food storage region, endosperm (cotyledon) etc.
- (vi) Breakdown of food reserves by hydrolytic enzymes into water soluble products.



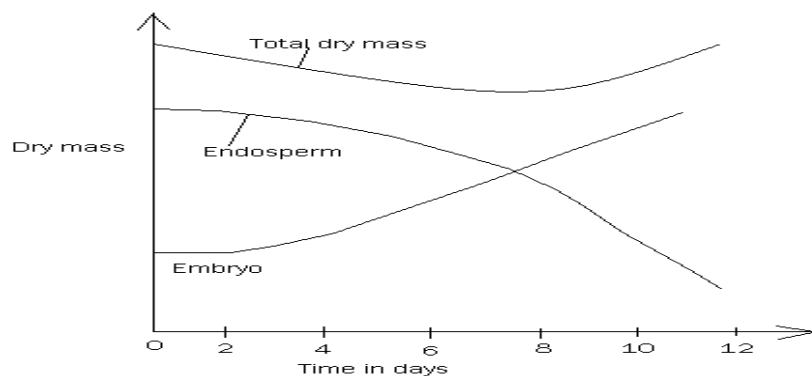
- (vii). Translocation of soluble products of digestion like sugar, amino acids, fatty acids glycerol to the embryo via the cotyledons.
- (viii). Utilization to these substances for respiration as well as for synthesis of others substance required for growth.

RELATIVE CHANGES IN DRY MASS OF ENDOSPERM AND EMBRYO DURING GERMINATION (E.g. Barley)

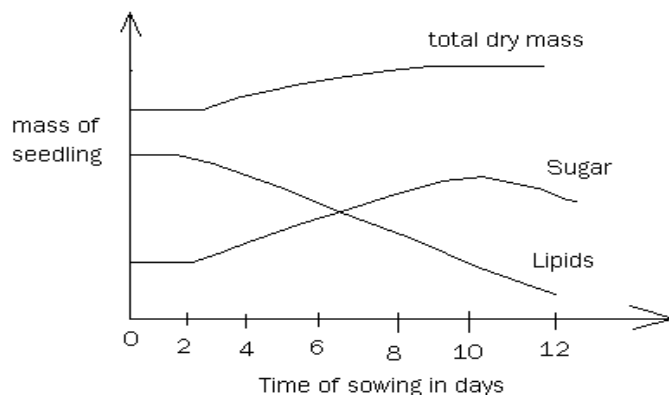
At the onset of germination, seed imbibes water; embryo is activated to secrete gibberellin which stimulates secretion of hydrolyzing enzymes such as alpha amylase, protease, and lipases. where alpha amylase breaks down starch to glucose, lipases breaks down lipids to fatty acids and glycerol, protease breaks down proteins to amino acids. The soluble products such as glucose, fatty acids, glycerol, and amino acids are translocated to the embryo for use in growth. Therefore endosperm's dry mass decreases while embryo dry mass increases.

At the same time, there is an overall loss in dry mass during the first week. This is due to aerobic respiration, which consumes sugar in both endosperm and embryo. At about seven, the first cotyledon emerges and starts to photosynthesize. The resulting increased in dry mass more than compensates greatly for respiration losses so that a net increase in dry mass is observed. At the same time the rate of growth of the embryo now a seedling increases.

GRAPH SHOWING CHANGE IN DRY MASS OF ENDOSPERM AND EMBRYO DURING SEED GERMINATION.



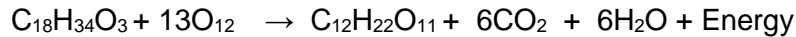
ANALYSIS OF CASTOR OIL SEEDS FOR LIPID AND SUGAR CONTENT DURING GERMINATION



The dominant food store in castor oil is lipid which comprises about 70% of the dry mass of the seeds before germination. By day 4 the mass of lipid is starting to decrease and the mass of sugar to increase. The lipid is therefore being converted to sugar and translocated to the embryo.

Note: that no sugars can be formed by photosynthesis since germination does not occur in darkness. At day 5 the RQ of the embryo = 1 indicating that the embryo is respiring the sugar (glucose) derived from lipids.

At the sometime, the cotyledons, RQ is between (0.4 – 0.5) indicating that it is gaining energy from the conversion of lipid to sugar and possibly from oxidation of sugar and fatty acids.



Where $\text{RQ} = \frac{6}{13} = 0.46$

Conversion of lipid to sugar takes place with an increase in dry mass so total dry mass of the seedlings increases up to 6 or 7 days. Beyond this point the lipid reserves are running low so rate of use of sugar starts to exceed the rate of its production net mass of sugar and total mass of seedlings then starts to decrease.

Sugar is used in respiration and in anaerobic reactions. At day 11, the RQ of the whole seedling would probably be slightly low or less than 1.0. It is a combination of two reactions. The main one is the oxidation of sugar in respiration $\text{RQ} = 1$ but there would probably still be a small contribution from the conversion of lipid to sugar $\text{RQ} = 0.4 - 0.5$.

MERISTEM

These are groups of actively dividing immature plant cells which form the only actively growing tissues. These tissues are called meristem there are 3 types of meristem.

Apical meristems

These are groups plant cell which can rapidly divide, they are found at the tips of the roots and shoots and are responsible for primary growth of the plant i.e. they increase its length.

Lateral/meristems

There are groups of plant cells which can rapidly divide, are found in cylinder towards the outside of stems and roots. They are responsible for secondary growth and cause an increase in girth.

Intercalary meristems

These are groups of plant cells which can rapidly divide, are found at the nodes in monocotyledonous plants. They allow an increase in length in position other than the tip.

A typical meristem cell possess the following characteristics.

- They are simple and undifferentiated.
- They are small in size and constantly dividing.
- Have a very a high metabolic activity.
- The nucleus is large and the cytoplasm dense.
- Their cell walls are thin.
- They have many smaller vacuoles.
- Are delicate.

The apical meristems are delicate cells and they need protection in the shoot, they are offered protection by the leaf primordia which partially encloses the tip. In the root, a root cap offers protection where physical damage is more likely because the tip is constantly being pushed through the soil.

A root cap is a layer of new cells which can be replaced when worn out by the activities of the apical meristem.

TYPES OF GROWTH.

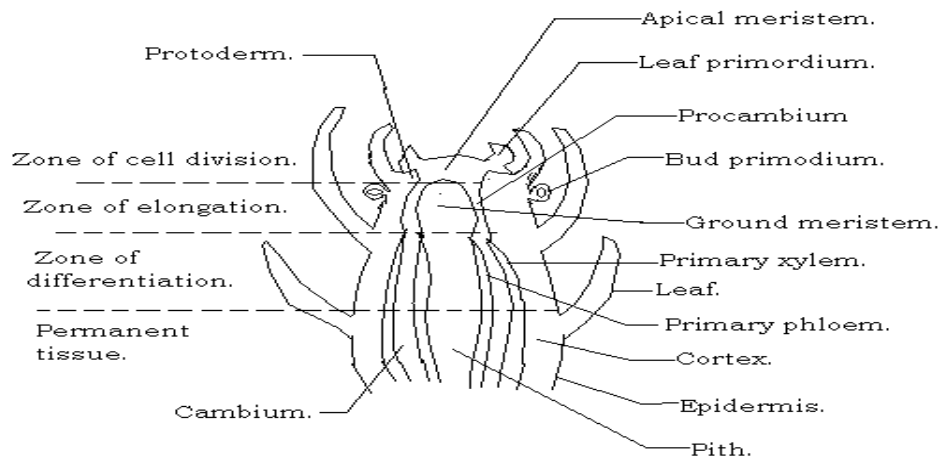
There are two different types of growth,

- (i) Primary growth.
- (ii) Secondary growth.

PRIMARY GROWTH.

Is the type of growth that occurs at the tip of the shoot and roots of a plant, resulting in an increase in length. It occurs due to activities of apical meristem.

LONGITUDINAL SECTION OF THE MERISTEM AT THE SHOOT APEX



PROCESS OF PRIMARY GROWTH.

Primary growth results in an increase in length of plants. This is due to the activity of apical meristem but intercalary meristem may also be involved. Primary growth is the first growth to take place in a plant in many plants.

At the apex of a stem or root, there are apical meristems, which are divided into different zones, there is a zone of cell division, which extends to 1-2 mm. This zone is composed of an outer layer called the tunica which consists of neatly arranged cells below it is a less organized layer of dividing cells called the corpus. Behind the zone of cell division is an area where the cells rapidly increase in size. This is the zone of cell elongation (expansion).

Further back is a region where the cells become specialized and alter their form and begin to perform different functions as they change into xylem, phloem, parenchyma, and sclerenchyma etc. This is called the zone of differentiation.

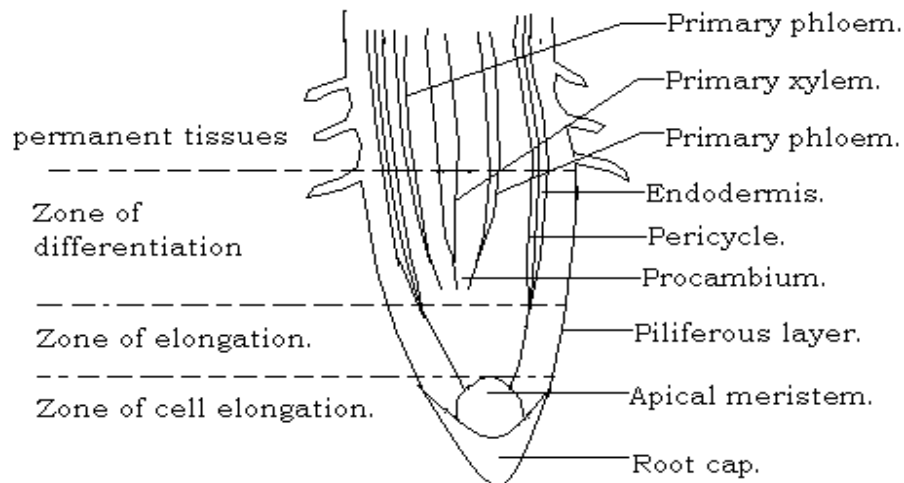
During cell expansion (elongation), small vacuoles in the meristematic cells unite to form large one which eventually form a single large central vacuole. This process is called **vacuolation**. At the same time, the cell wall thickens due to more cellulose being deposited. Some of the meristem cells do not vacuolate instead they remain meristematic in character and form long strands extending back from the apex these strands are called procambium. These procambium strands are the basis for the formation of vascular tissues. As they divide, the cells towards the inside of the pro-cambium form protoxylem and those to the outside form protophloem, later the procambium give rise to metaphloem and metaxylem which are longer cells and tend to crush the protophloem and protoxylem.

Differentiation of the apical meristem into parenchyma, Collenchyma, and sclerenchyma involve more than an increase in size and vacuolation. This depends on the extent of location and type of cellulose wall laid down.

Collenchyma has cellulose deposited at edges of the cell wall, and sclerenchyma tissues have the entire cell protoplast deposited with lignin. epidermal cells are derived from differentiation of tunica cells.

In roots, only a single central procambial cell strand is produced. Protophloem develops first from this strand followed by protoxylem. Finally, metaxylem and metaphloem develop as this differentiation occurs mostly at the centre of the procambium strand some of it remains to the outside. These are called pericycle and they retain their meristematic properties and can thus divide to give rise to lateral roots. Lateral roots develop from this pericycle which is deep within the root tissues. This formation arises from cambium which lies near the shoot surface. This formation is described as exogenous.

LONGITUDINAL SECTION OF A TIP OF A YOUNG ROOT SHOWING EARLY DEVELOPMENT (PRIMARY GROWTH).



SECONDARY GROWTH IN PLANTS.

SECONDARY GROWTH IN DICOTYLEDONOUS PLANTS

Secondary growth results into increase in the diameter or girth/thickness of part of a plant. It is also referred to as secondary thickening. It occurs due to rapid cell division at the lateral meristem. Lateral meristems are of two types.

Vascular cambium: this produces new xylem and phloem and is responsible for most of the increase in girth.

Cork cambium (phellogen). This produces a thick epidermal layer (periderm) which forms part of the bark.

The cells of the vascular cambium towards the outside (fusiform initials) divide rapidly and give rise to phloem tissue. While, cells of the vascular cambium (fusiform initials) towards the inside divide rapidly to give rise to xylem tissue. Xylem consists of xylem vessels and tracheids while phloem consists of companion cells and sieve tube elements. More xylem is formed than the phloem. The other cells of the vascular cambium called the ray initials divide rapidly to form the parenchyma between the neighbouring xylem and phloem. Collenchyma and sclereids are also formed.

The cells of the cork cambium/phellogen towards the outside divide to form cork cells beneath the epidermis. The cork cells become deposited with suberin as they mature and die off to form the **periderm**. The outer most layer form the bark. Lenticels are formed when the cork cells replace the epidermis. **Lenticels** are loosely arranged cork cells which permit gaseous exchange.

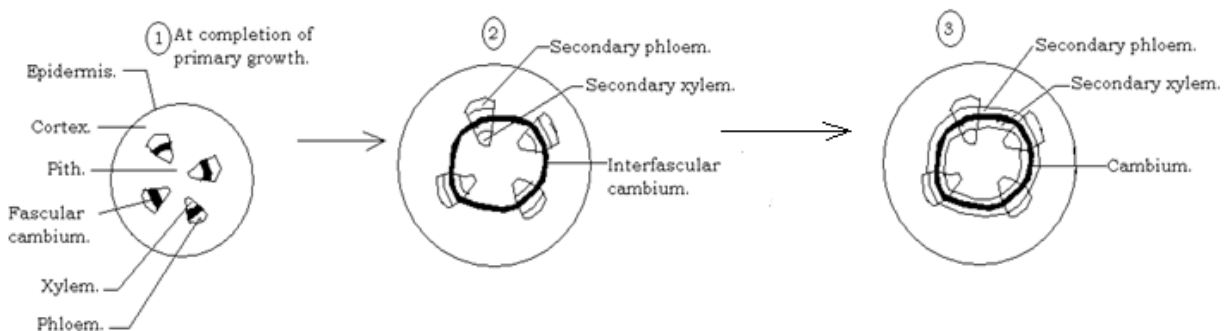
Cork cambium is located beneath the epidermis. The cell division of the cork cambium towards the inside form parenchyma, this tissue gives rise to secondary cortex.

The first stage of secondary growth in stems occurs when the vascular cambium grows to form a complete cylinder around the stem. New cambium formed between the vascular bundles is called **inter vascular cambium**.

As the amount of xylem formed is greater than phloem, over many years, the phloem becomes crushed and normally only the previous year's growth remains functional. The xylem remains functional for many years in the old tree, therefore a wide cylinder of functional xylem known as **sapwood** appear around the outside. At times, the xylem becomes blocked with various stored wastes such as tannins. This non functional xylem lies at the centre of the trunk and is called **heartwood**.

The growth of secondary xylem is not uniform throughout the year. Following rainy seasons the lumen of the xylem formed are larger and lighter, while after dry spells they are thinner and darker. This gives the appearance of a series of concentric rings when a trunk is cut transversely. These are called **annual rings**. Counting of these rings is an accurate means of estimating the age of a tree. In addition with width of any one ring gives an estimate of how favourable the climate was for growth in that year.

SECONDARY (LATERAL) MERISTEMS PRODUCING INCREASE IN GIRTH IN DICOTYLEDONOUS SHOOT.



STEP 1: At completion of primary growth.

STEP 2: Some parenchyma cells of pith rays become meristematic and form interfascicular cambium. Secondary xylem and phloem formed by fascicular cambium.

STEP 3: All cambium forms secondary xylem phloem so that complete rings develop.

SECONDARY GROWTH IN MONOCOTYLEDONOUS PLANT.

Monocotyledonous plants do not undergo secondary thickening but exhibit a slight increase in their girth due to formation of more ground tissues, consisting of mainly stem and root parenchymatous cells and scattered vascular bundles from the ground meristem produced from the corpus region of the apical meristem.

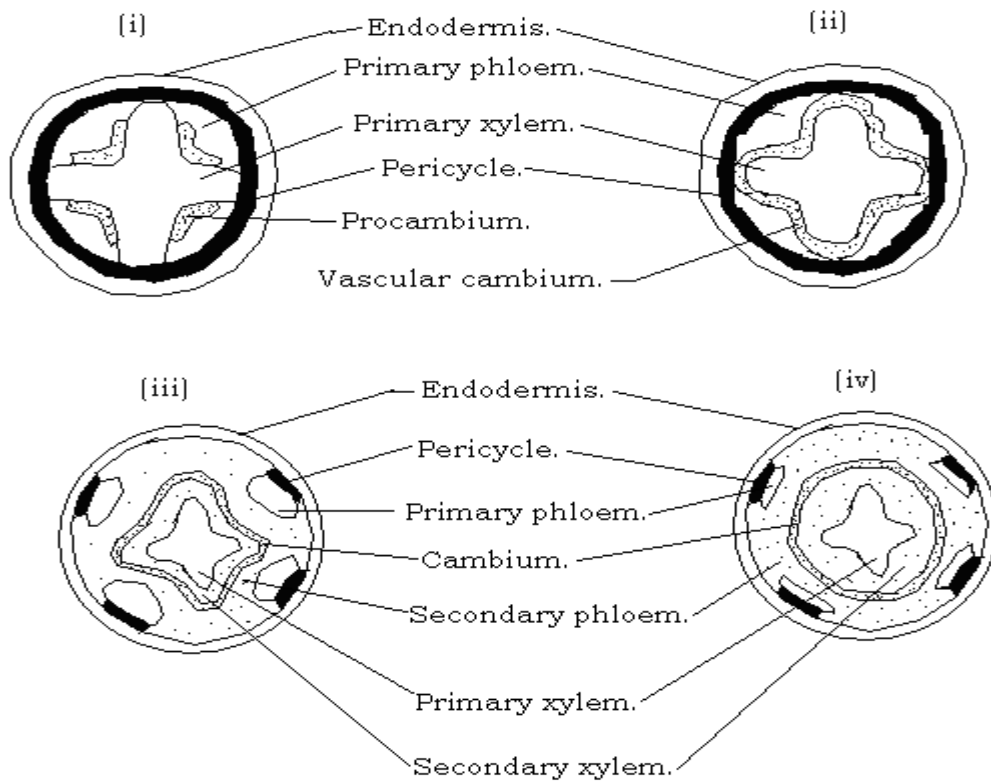
As the protoplasm enlarges into the metaxylem and protophloem into functional metaphloem, more water containing cavities or lysigenous cavities are formed from breakdown of inner protoxylem vessels and parenchyma to increase girth in stems and roots. The formation of more epidermis from the tunica region of the apical meristems and more layers of the hypodermis containing sclerenchymatous cells from the ground meristems also contribute to some increase in girth in monocots.

PROCESS OF SECONDARY GROWTH IN A ROOT OF DICOTYLEDONOUS PLANT.

Steps involved include,

- (i) At completion of primary growth a row of procambium remains and there is a complete Pericycle.
- (ii) Procambium joins with Pericycle outside xylem arms to form a complete ring or vascular cambium.
- (iii) The vascular cambium forms secondary xylem and phloem. The primary phloem is pushed outwards and a small amount of Pericycle is still associated with it.
- (iv) The vascular cambium forms a smooth cylinder giving rise to secondary xylem and phloem. The primary xylem remains in the centre but the primary phloem is crushed and only a small amount of Pericycle remains

SECONDARY (LATERAL) MERISTEMS PRODUCING INCREASE IN GIRTH IN A ROOT.



GROWTH AND DEVELOPMENT IN ANIMALS.

METAMORPHOSIS IN INSECTS.

During their life cycle, insects undergo metamorphosis. This is series of changes which take place from larval to adult forms. They usually involve a major re-organization of larval tissues. As we saw before there are two forms of insect metamorphosis.

- (i) **Hemimetabolous (incomplete metamorphosis).** The eggs hatch into larvae and then into nymph which clearly resemble the adults except that they are smaller, lack wings and are sexually immature. There are a number of nymphal stages between which moulting occurs. Examples of Hemimetabolous insects include locusts and cockroaches.

- (ii) **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, the tissues within the pupa, the adult (imago) emerges. Examples include moths, butterflies, and house flies.

DIFFERENCES BETWEEN COMPLETE AND INCOMPLETE METAMORPHOSIS.

COMPLETE METAMORPHOSIS	INCOMPLETE METAMORPHOSIS.
(i) Has distinct stages.	(i) Stages are similar except is size.
(ii) Sudden developmental changes.	(ii) Gradual developmental changes.
(iii) Changes occur in form and size.	(iii) Changes occur only in size.
(iv) Juvenile and adults have different diet.	(iv) Juvenile and adults have similar diets.
(v) Juvenile and adults have different habitats and behaviour.	(v) Juveniles and adults have similar habitat and behaviour.
(vi) Dormant stage is the pupa.	(vi) Dormant stage is the egg.
(vii) Has four stages/ has a larval stage.	(vii) Has three stages/ has no larval stage.

HORMONAL CONTROL OF INSECT METAMORPHOSIS.

The control of insect metamorphosis involves two main hormones;

- i. Moulting hormone (ecdysone) produced by thoracic gland called prothoracic gland
- ii. Juvenile hormone (neotinin) produced by a region behind the brain known as corpus allatum.

Metamorphosis in insects is mainly controlled by hormones from endocrine secretions and from neuro secretion. Environmental factors such as temperature, light period changes and distension of the body of the insect resulting from sucking of blood stimulate hormonal and neuro-activity within the insect. The activation of the neurosecretory center called pars intercerebralis stimulates the secretion of prothoracicotrophic hormone (PTTH) from the region of the insect brain called corpora cardiaca. It passes into the prothoracic gland possibly by axoplasmic streaming. Prothoracicotrophic hormone controls the secretions of the two hormones, moulting hormone (ecdysone) from prothoracic gland and Juvenile hormone (neotinin) from corpus allatum. Ecdysone stimulates the epidermal cells to produce new cuticle. A high concentration of the juvenile hormone causes a larval moult that is the insect remain as larva. All moults require ecdysone.

For incomplete metamorphosis, during larval stage, the action of ecdysone is regulated by that of juvenile hormone. This promotes the retention of nymphal characteristics thus preventing development into adult form.

For complete metamorphosis, high concentration of the juvenile hormone in absence of the ecdysone (moulting hormone) causes larval moults. This is the further development of larval stages i.e. larvae remains as larvae. High levels of ecdysone (moulting hormones) with low concentration of juvenile hormone, causes pupal ecdysis that is, the larva develops into pupa. High concentration of the moulting hormone (ecdysone) in a complete absence of juvenile hormone causes the pupa to develop into an imago (adult).

Once adult form has been attained in winged insects, the prothoracic gland degenerates, this does not occur in wingless insects. In adult insects the corpus allatum persists since it necessary for deposition of yolk in the egg and in males it is required for normal functioning of accessory glands which produce spermatophore.

Note: Amphibians are other organisms which can undergo metamorphosis like insects.

ADVANTAGES OF LARVAL FORMS.

- (i) Means by which sessile and slow moving organisms disperse to colonize other regions, this prevents over crowding and competition for scarce natural resources such as food, space etc.
- (ii) To exploit different food sources. For example, butterflies and moths feed on nectar as adults, where as, their larval forms, the caterpillars feed on leaves (foliage). This ensures maximum exploitation of food resources in the environment and avoids competition for food between adults and juvenile.

- (iii) Overcomes adverse environment conditions such as cold, drought by having larva which is better adapted to survive such extreme environmental conditions.
- (iv) To infect hosts and improve on their chances to survive. For example most platyhemintes parasites use larval stages to infect their hosts.

Note: Larvae actively feed but are sexually immature and can not reproduce. But sometimes larvae develop sexual organs and attain sexual maturity a condition called neoteny.

Pupa does not feed and is inactive and sexually immature.

HORMONAL CONTROL OF METAMORPHOSIS IN AMPHIBIANS (E,g TOADS AND FROGS)

This involves rapid changes of the organism from larval form to adult form. It triggered by changes in environmental conditions such as increase in temperature and changes in day length.

Changes in temperature and day length cause the hypothalamus of the larva to secrete thyrotrophin releasing hormone (TRH) into blood stream. Thyrotrophin releasing hormone stimulates the anterior lobe of the pituitary gland of the larva to secrete Thyroid Stimulating hormone (TSH) into blood stream. TSH in turn stimulates the thyroid gland to secrete thyroxine and triiodothyronine hormones into blood.

Thyroxine and triiodothyronine causes degeneration of the tails and external gills, mucus glands degenerate. The hormones in the process promote growth of operculum over the gills, the eyes become prominent, the head broadens, limbs emerge through the spiracles, mouth widens, lungs develop and the adult amphibian is developed.

GROWTH AND DEVELOPMENT IN VERTEBRATES

The development which follows fertilization in animals can be divided into 3 states.

- i. **Cleavage.** The mitotic division of the Zygote to form a mass of identical cells.
- ii. **Gastrulation.** The arrangement of cells into definite layers. These layers are ectoderm, endoderm and mesoderm. The embryo is known as gastrula at this stage.
- iii. **Organogenesis.** This is the differentiation of cells, tissues to form organs.

CLEAVAGE

Is the repeated mitotic division of the zygote without an increase in mass into a ball consisting of many daughter cells called Blastomeres.

After fertilization, the nucleus of the diploid zygote divides by mitosis, each division is accompanied by cleavage of the cytoplasm to form separate cells called Blastomeres. The mitotic cell divisions continue resulting into a spherical embryonic structure called the morula. The embryo does not increase in mass at this stage but the cells become small and smaller at each

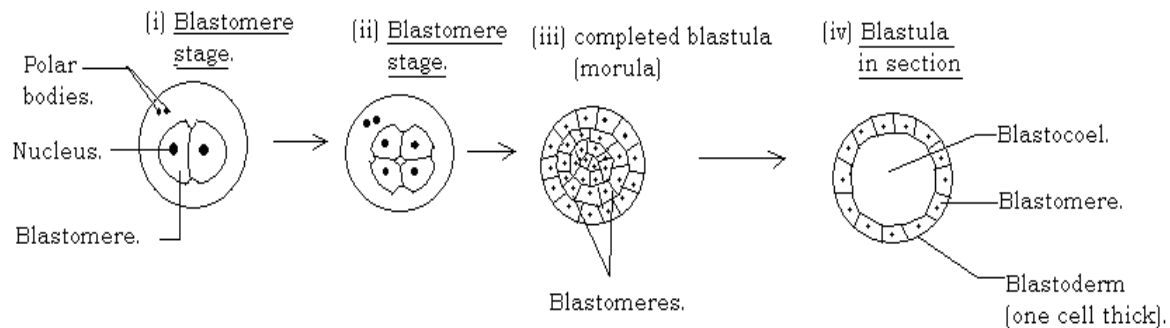
subsequent cell division. The cells then form a hollow sphere called Blastula. It has a fluid filled cavity known as Blastocoel.

The extent of cleavage depends on how much yolk is present as presence of yolk inhibits cleavage. For example,

In Amphioxus, the egg contains relatively little yolk and segmentation is holoblastic. This is where the cleavage of all cytoplasm occurs. The blastomeres are more or less equal in sizes although the eggs at the vegetal pole may be slightly larger and fewer due to accumulation of yolk. Yolk tends to limit the extent of cleavage.

In frogs, the egg is larger and contains more yolk. Cleavage is holoblastic but more unequal. The cells at the animal pole are smaller and more numerous than the yolky ones at the vegetal pole. The blastocoel is confined to the upper region of the blastula. In meroblastic cleavage, there is large amount of yolk and partial cleavage occurs in confined regions i.e animal pole as in fowl (birds).

CLEAVAGE IN AMPHIOXUS.



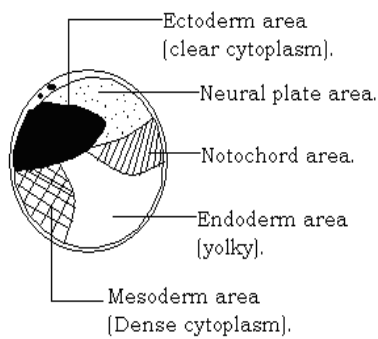
GASTRULATION

Gastrulation is the rearrangement of the cells (blastomeres) into three distinct layers, the ectoderm, mesoderm and endoderm in vertebrates.

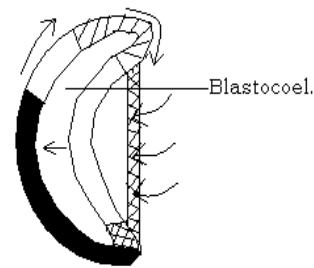
Gastrulation follows cleavage and results in formation of a hollow gastrula, it consists of a wall of two distinct cell layers and a cavity called archenteron. The blastoderm in chordates consists of presumptive areas (definite regions) that will give rise to distinct layers, the ectoderm, mesoderm, endoderm, neural plate and notochord. During gastrulation the cells of these presumptive areas migrate to their correct positions in the gastrula. The endoderm becomes the inner layer of the cell, ectoderm the outer layer, and the mass of cells between the two layers is the mesoderm. Gastrulation is modified by the amount of yolk present in the egg. In mammals, morula divides to form a hollow ball of cells whose wall is one cell thick and whose cavity encloses a mass of cells later develop into the germinal disc.

GASTRULATION IN AMPHIOXUS.

(i) Presumptive area in Blastula.

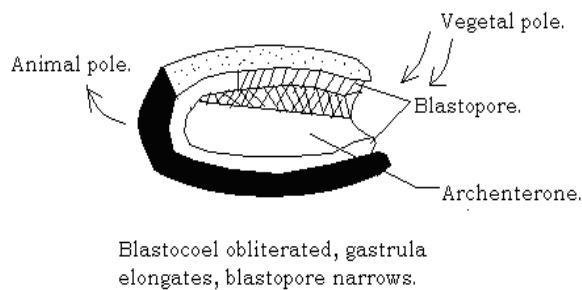


(ii) Movement of presumptive areas during gastrulation in Amphioxus.

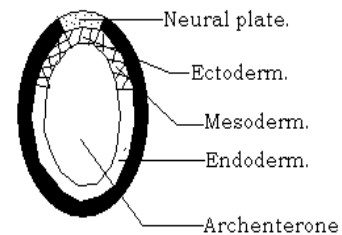


Invagination of cells of vegetal pole produced by more rapid rate of division of cells at animal pole.

(iii) Elongation of the gastrula.



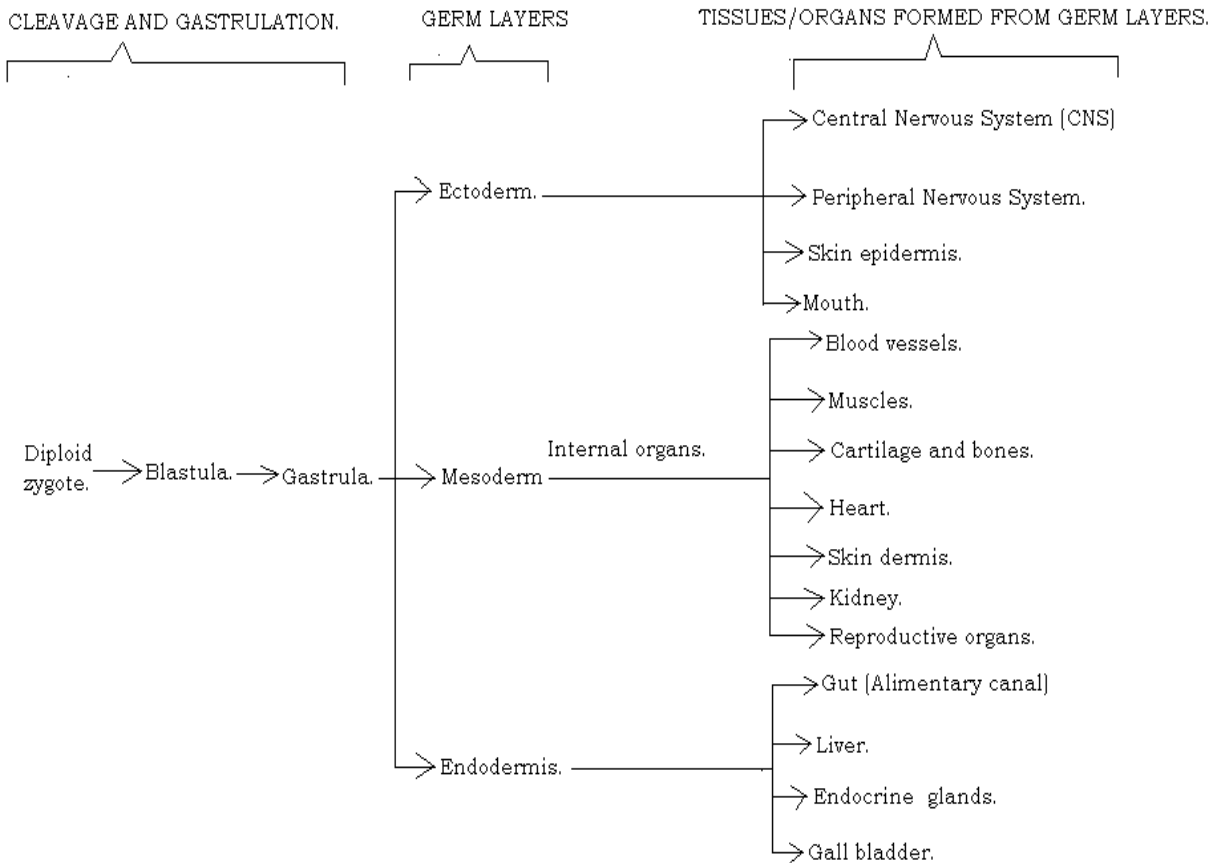
(iv) Transverse section of Gastrula.



ORGANOGENESIS

The cells of gastrula continue to divide and become differentiated. The ectoderm folds inwards to become the neural tube which later develops into the neuro-chord of which the anterior part expands to form the brain. The embryo at this stage is called the neurula. The mesoderm forms the notochord which in vertebrate is replaced by the vertebral column. The gut increases in length. Major organs such as the liver, pancreas, endocrine glands etc develops from the endoderm. Notochord is an elongated tube anterior to which lines the gut (endoderm) and posterior to which lines the neuroplate (spinal chord).

THE THREE GERM LAYERS AND THE TISSUES FORMED FROM THEM,



HORMONAL CONTROL OF GROWTH AND DEVELOPMENT IN HUMANS.

Human growth and development is under the control of hormones secreted by the hypothalamus and the pituitary gland. Growth in human is stimulated by **Human growth hormone (HGH)** also called **somatotrophin** secreted from the anterior lobe of pituitary gland. The secretion of human growth hormone (somatotrophin) is under the direct control of the hypothalamus. Secretion of the Human growth hormone from the anterior pituitary gland is stimulated by **growth hormone releasing hormone (GHRH)** also known as **somatocrinin** secreted from the hypothalamus. Somatotrophin has an effect on all parts of the body but particularly on growth of the skeleton and skeletal muscles. It also stimulates the release of small protein hormones called **somatomedins** (insulin-like growth factors or IGFs) from the liver. This hormone regulate the activities of the Human growth hormone (hGH) resulting to stimulation of bone growth. The secretion of the somatotrophin from the anterior lobe of the pituitary is inhibited by the **Growth Hormone Inhibitory Hormone (GHIH)** secreted by the hypothalamus.

The effects of the Human Growth Hormone on the growth and development of all the body parts include the following,

- Increased growth of skeleton and skeletal muscles during childhood and adolescence.
- Maintenance of muscle size and bone size in adult and promotion of tissue repair.
- Increased rate of uptake of amino acids into cells.

- Increased rate of protein synthesis.
- Increased rate of cell growth and cell division.
- Increased use of fats in respiration (instead of amino acids and glucose).
- Decreased uptake of glucose by cells.
- Increased level of glucose in blood.

There are other hormones that play similar role in control of growth and development in humans. Thyroxin and triiodothyronin secreted from the thyroid gland. These hormones stimulate protein synthesis which is important in stimulating growth of the skeleton. Sex hormones secreted from the gonads. They are responsible for growth and development and stimulate development of the secondary sexual characteristics. Steroid hormones secreted by the adrenal cortex in both sexes. These include the small amounts of both female and male sex hormones and these are, Oestrogens and androgens. The androgens stimulate the adolescent growth spurt and development of pubic hair and underarm hair in both boys and girls.

In 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 sexual behaviours in females (sex drive).

Over production of human growth hormone during child hood results in the person growing into becoming a giant a condition referred to as **Gigantism**. Since bones are still capable of growth. In adult hood, over production of human growth hormone, results into enlargement of the hands, feet, skull, nose and jaw bones. A condition known as acromegaly. This is because the bones are no longer capable of increasing in length but under the influence of excess human growth hormone, the bones continue to grow in thickness together with an increased growth of the soft tissues resulting into the acromegaly.

A deficiency of the human growth hormone results into a condition known as **pituitary dwarfism**. In this case the victim grows much more slowly. Some conditions of the dwarfism, for example the dwarfism among African pigmies is caused by deficiency of the somatomedins.

FACTORS AFFECTING GROWTH AND DEVELOPMENT OF ORGANISMS.

These factors are catagorised into hereditary and environmental factors.

HEREDITARY FACTORS.

(i) Expression of genes.

Dominant and recessive alleles determine certain metabolic reactions such as protein synthesis, respiration at different rates. The maximum size of an individual is determined by the genotype. Presence of some substrate in the culture medium such tryptophane may switch off genes and lower process of growth.

(ii) Protein or enzyme synthesis.

Presence of enzyme in the cell speeds up certain metabolism in the cell and hence protein synthesis. Alters rate of growth and development in individuals.

(iii) Selection of genes.

This may occur through natural selection of genes, changing environmental conditions. Stable environmental conditions allows expression of variety of genes.

(iv) Hormones.

Hormones such as somatotrophin and thyroxine stimulate rapid growth in humans, while somatocrinin inhibit growth. In plants, auxins and gibberellin hormones promote cell elongation, fruit growth. While Abscissic acid inhibit growth of the embryo in the seed.

ENVIRONMENTAL FACTORS.

In plants:

Temperature.

Suitable temperatures are needed for photosynthesis, germination, growth, flowering and water and mineral salts uptake by the roots of the plants.

Light.

Needed for photosynthesis, Photoperiodism, germination, length of light affect the time of flowering.

Oxygen.

Needed for germination and respiration. Aerobic organisms need oxygen for respiration and hence energy for growth and development. Anaerobic ones do need oxygen.

Water.

Necessary as raw materials for photosynthesis, dissolution of ions and rapid uptake and transport of sugars and mineral salts. Activator of enzymes in seed germination.

Mineral salts,

Magnesium in chlorophyll for photosynthesis, nitrogen for protein synthesis.

In animals.

Food.

Animals need proteins, fats, carbohydrates, vitamins, mineral ions and water.

Space.

To provide territory, avoid diseases to due to overcrowding, little space may lower reproductive potential of individuals.

Diseases.

Disease infections lowers growth rates, disease free organisms have higher rate of growth.