GROWTH AND DEVELOPMENT

Introduction:

Growth is as an irreversible or permanent increase in the size and dry weight of an organism. In multicellular organisms, growth involves the following:

1. **Cell division**: This causes increase in the number of cells. It's mainly as a result of mitosis.
2. **Cell expansion**: This is the permanent increase in the cell size as a result of uptake of water or synthesis (manufacture) of living materials.
3. **Cell differentiation:** This involves specialization of cells to suit particular functions.

NOTE: To suit particular functions, cells usually undergo changes both in their shape and form. They join others of similar kind to form tissues and then organs. Such cells do not divide any more thus growth is usually accompanied by an increase in the complexity of the organism which is also called **development**.

Development is the increase in complexity of an organism.

Growth is one of the characteristics of organisms which distinguishes from non-living things.

Factors affecting growth in plants and animals

External conditions:

i) Nutrient availability:

Growth of an organism increases with availability of nutrients and decreases when nutrients are in short supply. This is because nutrients are used in the building up of new cell components. Also, nutrients can be broken down to provide energy required for growth. Therefore, lack of nutrients can lead to decrease in growth or even death.

ii) Accumulation of the by-products of metabolism (or excretions)

Growth is reduced by metabolic waste products which are toxic to the body cells. Organisms like plants and animals must convert these substances to less toxic substances and excreted to enable continuity of growth.

Growth in Yeast and some bacteria is lowered by accumulation of wastes like alcohol resulting from the process of putrefaction (decay) and fermentation.

iii) Temperature:

Growth, just like other biological processes is controlled by enzymes hence affected by temperature change. When the temperature increases to the optimum temperature, growth increases, and beyond the optimum, growth reduces.

iv) Light:

In plants, light affects growth by affecting the rate of photosynthesis which adds more organic matter to the plant. Therefore, increase in light intensity in green plants increases the rate of growth and decrease in light intensity decreases the rate of growth.

v) PH:

The PH affects the activity of enzymes which catalyses reactions in the body. Change in PH can result into decrease in growth of an organism. Organisms will have fast growth in a given range of PH. PH changes in the soil affects the growth and functioning of plant roots mainly due to the effect on enzymes.

Internal conditions

i) Hormones:

In animals, the presence of growth hormones and thyroxine in blood increases the rate of growth while in plants the presence of auxins increases the rate of growth.

ii) Hereditary factors:

Growth is under the control of genes which determines the particular size of an organism, a mixture of all these factors together with the genes of an organism cause maximum growth.

GROWTH AND DEVELOPMENT IN PLANTS

In plants, growth is continuous processes which occurs mainly at the tips of the root and shoot systems. These regions where growth occurs in plants are called **meristems.** ***A meristem*** *is a group of undifferentiated plant cells which are capable of continuous dividision by mitosis.*

Types of meristems

i) Apical meristems

These are located at the tip of roots and shoot. They cause an increase in length or height of the plant. This type of growth which involves increase in length or height of a plant is known as **primary growth.**

ii) Lateral meristems

These are laterally situated in the stems and roots of the dicot plants. It brings about **secondary growth** after primary growth. Secondary growth (secondary thickening) involves increase in girth/thickness in a plant.

Lateral meristems are of 2 types namely:

- Cork cambium; which forms the secondary cortex
- Vascular cambium; which gives rise to the secondary phloem and xylem tissues.

In plants, there are two types of growth:

Primary growth: this is a type of growth which causes increase in the length or height of the plant. It starts at germination and continues at the apical meristems.

Secondary growth: this is a type of growth which causes increase in girth of the stem, for which reason it is known as **secondary thickening**. It occurs in dicot woody plants at the lateral meristem. Secondary growth is also important in wound healing and regeneration of plants parts in woody species but most importantly to increase the girth of the stem to provide additional support of the plant above the ground.

Seed structure, germination and dormancy

Seed structure:

Basing on the nature of the food reserves can be grouped into endospermic i.e. those with an endosperm like castor oil and maize (this is actually a one seeded fruit) and non-endospermic i.e. those without endosperms e.g. beans, peas which store their food reserves in two cotyledons. The latter group can also regroup into monocotyledons if food is stored in one cotyledon e.g. in maize and dicotyledonous if food is stored in two cotyledons e.g. in beans.

Seed germination:

This is the development of an embryo into a seedling. A seedling is a developing embryo capable of existing as a new and independent plant under favourable conditions.

The process of germination

During germination, a seed osmotically absorbs water from the **soil** by **imbibition** mainly through the micropyle. This makes the cotyledons swell, testa weakens and splits. The water activates enzymes in the cotyledons to hydrolyse (break down) the stored food into soluble products which are used by the germinating seed.

The enzymes involved in hydrolysis include diastase, protease and lipase. The soluble food substances diffuse into the cell where it is required for the growing embryo. Simple sugars and fats are broken down to produce energy. Amino acids are used to make new cells. Growth of the radicles and plumule occurs and cause rapture of the seed coat and an embryo emerges.

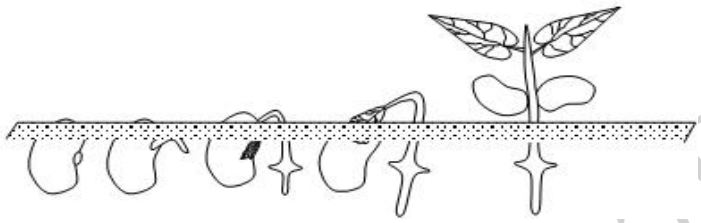
TYPES OF GERMINATION

1. Epigeal germination

This is a type of germination where the ***cotyledons appear above the ground due to the rapid elongation of the hypocotyl*** (i.e. the portion of the stem below the cotyledons) e.g. in tomatoes, beans, cotton.

During epigeal germination the seed absorbs water through the micropyle in a process called imbibition. This softens the testa and makes the cotyledons to swell. The water activates enzymes, which hydrolyse the stored food reserves and the products are moved from the cotyledons to the radicle and plumule where they are used for growth. The radicle emerges first and the hypocotyls start to elongate pushing the cotyledons upwards. The cotyledons may turn green in some plants and can carry out photosynthesis. The cotyledons open to allow out the plumule. The leaves are formed and they start to photosynthesize.

Diagrammatic illustration of epigeal germination

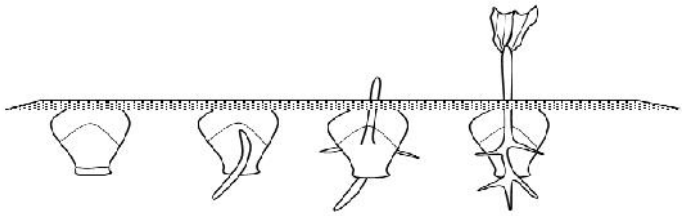


2. Hypogeal germination:

This is type of germination where the ***cotyledon remains below the ground due to the rapid elongation of the epicotyl*** (i.e. the portion of the stem above the cotyledons) e.g. in maize.

During hypogeal germination, the seed absorbs water by imbibition. The radicle appears first bursting its protective sheath called coleorhizae. The radicle produces fibrous roots, which absorb water and anchor the plant. The protective plumule sheath (coleoptiles) opens to allow the plumule out. The epicotyls elongate pushing the cotyledons below the ground.

Diagrammatic illustration of hypogeal germination



Conditions necessary for seed germination:

When the seed is dispersed from the plant it is usually very dry and, in this condition, growth cannot take place so the embryo remains dormant with in seeds until conditions are suitable for its growth. This renewal of growth is germination and require the following conditions:

External conditions:

Water: Water is needed for the following:

- Activates the enzymes within the seed to hydrolyse the stored food.
- It makes the seed swell, soft and the testa to bursts for easy passage of radical and plumule.
- It dissolves the stored food for easy absorption.
- It is a medium in which all the chemical and enzymatic reactions proceed.
- It is a medium of transport of the dissolved food substances to the developing shoot and root of the new plant.
- It is needed for the development of cell vacuoles. Large cell vacuoles contribute to increase in size of cells.

Oxygen: Oxygen is necessary for the process of respiration to breakdown food to provide energy required for growth.

Suitable temperature: Seeds need an optimum temperature to germinate. Usually there is no germination below 0^0C or above 45^0C. This is because high temperature destroys the enzymes of the cells while low temperature makes the enzymes inactive.

Internal conditions:

Enzymes: control the utilisation and respiration of food substances. This is because the carbohydrates, proteins and lipids stored in seeds need to be broken down into smaller soluble molecules in order to be used by developing embryo.

The enzymes required are diastase for carbohydrates like starch, lipase for lipids and proteases for protein. Enzymes are also necessary for the conversion of some of the hydrolysed products to new plant tissues.

Energy: is quite necessary for the maintenance of the activities of the rapidly developing and growing embryo. It is obtained from the food stored in the food reserves (cotyledon or endosperm) of the speed.

Viability: this is the ability of a seed to germinate when favourable conditions are present. Only seeds that have life and are healthy will germinate and grow, seeds (cotyledon or endosperm) of the seed.

EXPERIMENTS ON GERMINATION

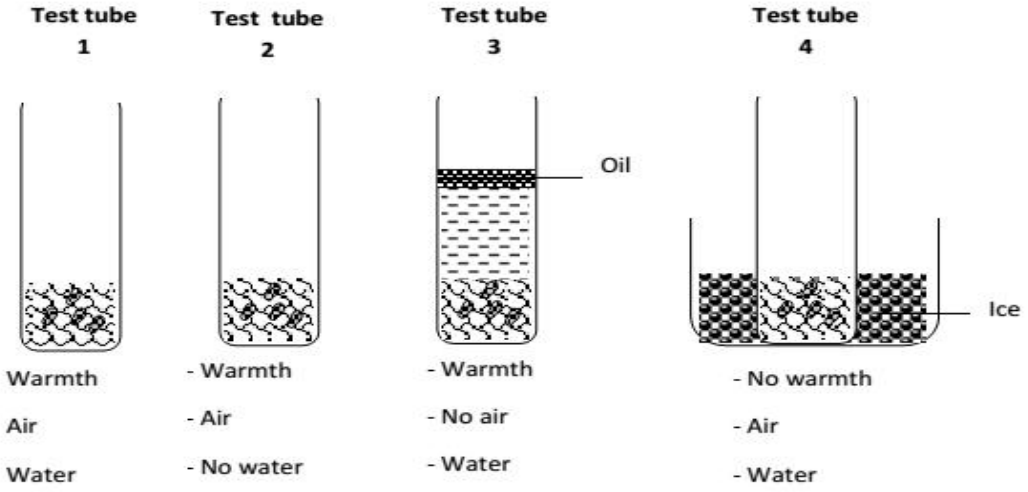
An experiment to demonstrate the conditions necessary for germination

Apparatus: 4 test tubes, Cotton wool, Seeds, Oil and Water.

Procedure:

- Arrange four test tubes labelled 1-4
- To test tube 1, add moist cotton wool, seeds and leave test tube open.
- To test tube 2, add dry cotton wool, seeds and leave test tube open.
- To test tube 3, add seeds, boiled cooled water and a layer of oil.
- To 4 add seeds, moist cotton wool, ice and leave test tube open. Leave all test tubes for 3 days.

Setup:



Observations

Seeds germinated in only test tube 1 and those in 2, 3 and 4 did not germinate.

Conclusion:

Air, water and warmth (suitable temperature) are necessary for germination.

Experiment to show that oxygen is necessary for germination

Apparatus:

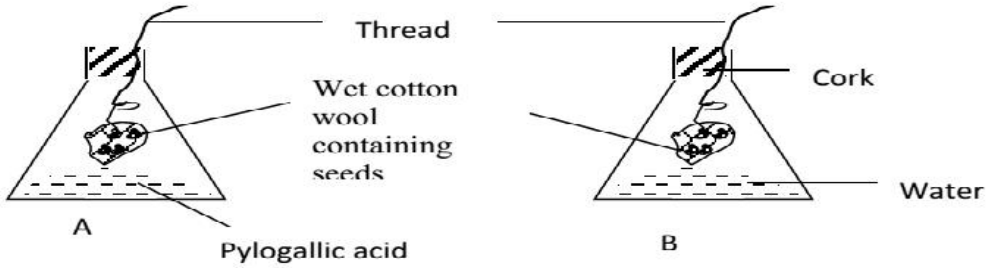
- 2 conical flasks, 2 corks, Water, Cotton wool, Seeds and Pyrogallic acid.

Procedure:

- Pour some water in one conical flask and some alkaline pyrogallol in another conical flask.
- Tie some seeds in wet cotton wool and suspend the cotton wool in the flasks using a thread.

- Fix the threads using a cork.
- Leave the set up for three days

Set up:



Observation:

After a few days the seeds in B germinated while those in A did not germinate

Conclusion:

Oxygen is necessary for germination.

Explanation:

Alkaline pyrogallol absorbs oxygen from air in flask A thereby preventing germination

Experiment to show that water is necessary for germination

Apparatus

- 4 petri dishes, cotton wool, water, seeds

Procedure

- Label four petri dishes 1,2,3 and 4 and prepare them as follows
- In 1, places seeds that have been soaked for 24 hours on moist cotton wool
- In 2, place seeds that have been soaked for 24 hours on dry cotton wool
- In 3, place dry seeds on dry cotton wool
- In 4, place seeds soaked completely and covered with water.

Note: Use equal number of seeds and type in each petri dish and cover them. Leave the experiment in the same conditions of light and temperature for five days.

Observation

- Proper seed germination takes place only in petri dish 1, those in dish 2 begin germinating but later die out. Those in dish 3 did not germinate, while those in 4 rot.

Conclusion: Water is necessary for germination but excess water prevents germination

Explanation: Excess water cuts off oxygen supply hence preventing germination.

Experiment to show that suitable temperature is necessary for germination

Apparatus;

- Soaked seeds, moist cotton, 3 petri dishes

Procedure

- Label three petri dishes 1,2 and 3. Place equal numbers of soaked seeds into each of them on moist cotton wool.
- Place dish 1 at room temperature, dish 2 in an incubator at 30^0c and dish 3 at 4^0c in a refrigerator.
- Leave the experiment to stand for one week, maintain constant temperature in each dish.
- Compare the extent of germination in each o the three dishes.

Observation

Most germination occurs in dish 1 and least germination occurs in dish 3. Moderate germination occurs in dish 2.

Conclusion: Adequate temperature is necessary for proper germination
Explanation; Higher temperature kills the cell protoplasm and denatures enzymes, hence preventing germination
Lower temperature inhibits enzyme activity hence preventing germination

MEASUREMENTS OF GROWTH
Growth in n organism can be measured by finding out the changes that occur in the organism like changes in weight, height, length, width, surface area.

1) Measurement using change in weight

Measurement of growth using weight is divided into two i.e. use of fresh weight and use of dry weight of a seedling.

1. Fresh weight/mass:
This is the total amount of organic matter and water in an organism.
Advantages of measuring growth by using the fresh weight of an organism

- It does not involve the killing of the organism.
- It is a very method of determining growth.
- It is the most suitable method of determining growth of seedlings.

Disadvantages of measuring growth by measuring the fresh weight of an organism

- It is less accurate since the biggest part of an organism is water.
- It is not reliable because the mass keeps on fluctuating due to water loss by transpiration and evaporation.

2. Dry weight/mass
This is the total amount of organic matter making up the body of an organism after removing water. It involves heating of an organism in an oven to a constant weight
NOTE: Dry weight is the best method of determining growth because it measure the actual amount of organic matter of an organism.
Advantages

- It is a more accurate method of determining growth.
- It is reliable because constant results are obtained.

Disadvantages

- It involves killing of an organism.
- The volatile tissues may decompose before removing all the water.

2) Measurement using changes in area
This involves determining the area of a part by tracing it on a graph paper. Multiply the area by 2 to obtain the surface area. It is measured at specific time intervals

3) Measurement using changes in length
Using a ruler, one can measure and determine the growth of a plant part like roots, leaves or stems.
Advantage

- Organism is not killed
- It is easy to use

Disadvantages

- It assumes growth in length is proportional to growth in other dimensions
- Plant parts tend to grow at different rates

Experiment to determine the region of growth in a root and shoot

- Bean seeds are germinated in a damp cloth so that the roots are straight.
- One of the straight roots is marked starting at the tip with equal spaces of 1mm each with permanent ink.
- After a few hours it is found that as the shoot grows downwards.
- The equal spaces of 1mm are maintained at the upper positions of the root except near the root tips where the interval between the marks become wider.

Illustration:

a) start of experiment **b) end of experiment**

This shows that all growth in length of root takes place close behind the root tip. In fact, if the tip of the root is cut off growth ceases for a while.

The shoot: a growing bean seeding with upright stem is selected and marked out with permanent ink at intervals of 5mm. the seeding is examined every 24 hours. It is discovered that as the stem grows, nearly all the marks get farther apart.

This shows that growth in stem is not confined to a very short distance as in roots but that it is spread over a great length of the stem. However the intervals become more wider near the tip.

Illustration

CHANGES IN DRY WEIGHT OF A GERMINATING SEED

The dry weight is a weight of a substance or organism after all the water in it has been removed by heating as opposed to the fresh weight which is the weight of an organism as measured at any one time as it lives. Dry weight is one sure way of determining the growth of an organism because it shows how much new organic material has been added to the organisms' weight per unit time.

Graph showing changes in the dry weight of a germinating seedling

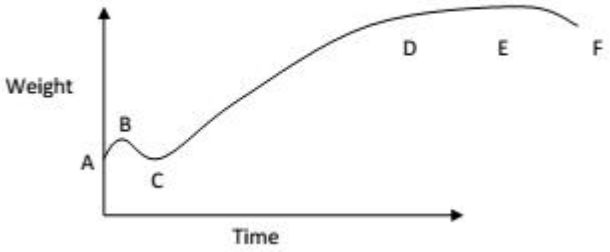
This is called the sigmoid curve (S shaped) which is true for growth of most organisms

Description and explanation of the graph:

1. Lag phase.
This is a period of slow growth. It is the period of growth where there are very few cells dividing and the organism is getting used (adapted) to the environment.
2. The log phase (exponential phase).
This is a phase of rapid growth. It is the phase where the cells dividing are many and the organism is used to the environment.
3. Decelerating growth phase.
This is a period where growth slows down. The deceleration in growth may be due to;
1. Competition for food, space and other resources.
2. The organism is preparing for reproduction.
3. The organism is aging.

4. The stationary phase.
This is a period where the growth is constant. At this point the number of cells, which die is equal to those produced. The organism has reached maturity and hence has maximum size. There is no change in size.
5. Decline growth phase
After the stationary phase, the growth decelerates due to aging, senescence has reached and cells dying are more than new cells formed. In perennial organisms, growth increases continuously.

CHANGE IN TOTAL WEIGHT OF A GERMINATING SEED.



Explanation of the graph:
Most of the changes are similar to those in the graph showing changes of dry weight with time in a germinating seed except that for dry weight, the weight of water in the seed is not considered. For the total weight of the seed during germination, water is put into consideration.
The initial slight increase in weight from point A-B is due to imbibition (absorption) of water into the seed. The other changes that follow in the subsequent points on the curve are similar to those in the change of dry weight with time.

Seed dormancy: this is the state in which seeds will not germinate under normal germination conditions.
Causes of seed dormancy: seed dormancy may be due to the following:

1. **Environment causes:** This is due to lack of some factor in the environment other than air, water and warmth. This could be due to factors like light or soil conditions like pH, or presence of germination inhibitors.
2. **Structure of the seed coat:** some seeds have testa which are hard, impermeable to water and air, inhibiting the emergence of the embryo.

Such dormancy is normally broken naturally (but after sometime) by such processes like:

- Microbial attack by soil fungi and bacteria which causes it to decay.

- Passage though the guts of animals like birds and mammals which eat the fruit in which the seeds are found e.g. passion and tomato. The hard seed coat is weakened by the enzymes and hydrochloric acid in the guts of these animals.
- Cracking due to exposure to alternate heating (during the day) and cooling at night.
- This dormancy could be broken much faster and hence accelerating germination by such artificial means like:
- Filing the testa to make it soft or thin.
- Churning the testa with concentrated solution of sulphuric acid.
- Dissolving the testa in alcohol.

3. **Physiological state of the seed:** Due to some conditions during development, the embryo itself may be immature or dormant and thus incapable of undergoing further development at the time the seed is planted.

Such dormancy is broken by allowing the embryo time to develop to maturity if it is immature.

This is called the period of after ripening. If the embryo is dormant a growth promoter like gibberellin acid needs to be applied to make it active again.

4. **Presence of germination inhibitors:** these may be either in the seed itself or in the soil from where they enter the seed as it imbibes water prior to germination. Such inhibitors mitosis, enzymes reactions and overall growth. One such inhibitor is abscissa acid.

Uses of seed dormancy to plants:

Seed dormancy on the outright seems to be more of a problem to plants than any advantage. In essence however the following advantageous aspects of seed dormancy are worth mentioning as uses:

- It allows seeds to germinate only during favourable conditions.
- It allows seeds to germinate only when the embryo is fully mature. This is necessary if the seeds are to give rise to healthy and strong plants.
- It allows food storage in seeds and their preservation as food.

GROWTH IN ANIMALS

In animals, growth occurs throughout the body of the organism unlike in plants where growth is localized in specific areas called meristems. Most animals grow continuously until they reach maturity. This is called continuous growth. In Arthropods like insects, growth is discontinuous, i.e. there are periods of growth and no growth.

Comparison between growth in plants and animals

Similarities

Animal growth is essentially similar to plant growth. This is because: -

- Increase in size and weight also occurs due to the formation of new cells by cell division and the enlargement of existing cells (i.e. cell expansion).
- Food, water, oxygen and suitable temperature are still required and
- The rate of growth is controlled by diet, and hormones.
- A plot of growth rate of animals (except arthropods) give the S – shaped curve as seen in plants. However, a number of differences are worth mentioning.

Differences

i Growth is also restricted to specific regions of the animals but takes place over the whole body (and is termed as **internal growth).**

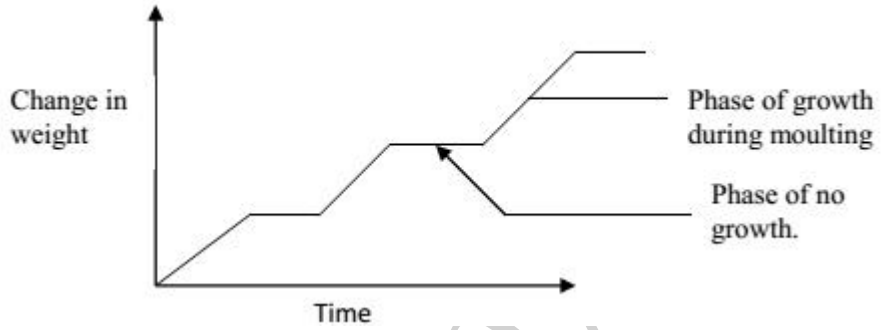
ii Most animals grow in period between birth and adulthood when growth ceases (except some invertebrates which tend to grow continuously like plants)

GROWTH AND DEVELOPMENT IN INSECTS

Insects have an exoskeleton which is rigid and prevents expansion of the insect during growth. Before the insect grows, it sheds the exoskeleton in a process called moulting (ecdysis). Growth is therefore said to be intermittent. This is due to the presence of hard cuticles (exo skeletons) which prevent continuous growth and must be shed before any growth can take place. Shedding of the cuticles (**ecdysis** or **moulting**) is immediately followed by a quick expansion to a new size usually by talking in air (or water if the insects has an aquatic habitat) before the new cuticle hardness. Growth is therefore discontinuous. The periods of no growth (or constant size) between moults being called **instars.**

Without the exoskeleton, the insect expands and grows. A new exoskeleton then forms and growth ceases. This kind of growth is referred to as intermittent growth or discontinuous growth. Successive moults result into formation of a new form of the insect. This is called metamorphosis. Metamorphosis has already been discussed under insects.

Fig. 8.5 The insect growth curve



Growth in vertebrates:

After fertilization, the zygote undergoes three changes during its growth and development. These changes are;

1. **Cleavage:**

This is the mitotic division of the zygote to form a mass of cells. The zygote at this stage is called a **blastocyst**.

2. **Gastrulation.**

This is the rearrangement of the cells into distinct layers. The outer cells make up a layer called ectoderm. The cells in the middle make up a layer called mesoderm and the inner cells make up the endoderm. From these layers the various organs and systems are formed.

3. **Organogenesis:**

This is the formation of organs and organ systems

Growth in amphibians:

This demonstrates how growth proceeds by metamorphosis (change from) and change in diet. The main features are:

- Eggs are laid by females followed by fertilisation in water (i.e. external fertilisation).

After 30 hours. Hatching of the eggs into larva or tadpoles with a short tail which gradually lengthens. Breathing is by external gills. The young tadpole is non motile and remains so (usually fixed to vegetation using mucus from their mucus glands). At this moment the tadpole also has a straight gut but no mouth.

4 – 8 days. Later special sense organs develop e.g. nasal sacs, eyes and inner ears, the gut becomes long and coiled and thus suitable for an herbaceous diet, a mouth develops followed by horny jaws with small teeth, and it begins to feed on vegetation like algae.
8 – Weeks. The external gills become replaced by internal gills and operculum develops.
8 – Weeks. Limbs buds appear which gradually develop into paired libs, hind limbs appearing first followed by the fore limbs.
8 weeks. A pair of lungs develops these are not yet functional.
10 – Weeks. The tadpole then undergoes a sudden metamorphosis into the adult which can also live on land. The important changes that occur here in summary are:

- Nasal sacs acquire internal openings not the pharynx and buccal cavity.
- Eyelids develop allowing the eyes to be used on land without threat of desiccation.
- Middle ear develops and functional tympanic membrane develops. The adult can therefore respond to sound waves in air characteristics of the land environment.
- Mouth widens, horny jaws and teeth are placed by true jaws and teeth. Jam muscles and a tongue develop.
- Skull bones develop resulting in the head changing shape.
- The limbs increase in size, the pelvic girdle develops resulting in the characteristic humped back appearance of the adult.
- The tail shortens and gradually disappears. Its cells are broken down and are reabsorbed.
- The colour pattern characteristic of the adult develops.
- The gut shortens this being associated with the change from an herbivorous to a carnivorous diet.
- The crustacean tube develops.
- The heart completes its development to 3 chambers and a double circulation ensures.
- Finally, the lung become functional. All these changes are controlled hormonally by the hormone thyroxin. Thus, growth here differs from that in insects by lack of a pupa stage and involves modification of existing structures other than their total replacement as seen in insects.

Growth in mammals:

Growth in mammals conforms to the normal S-shaped curve. Beginning internal fertilisation and development of the zygote by cell division and differentiate followed by implantation into the uterine wall where internal development proceeds. Involving the development of a placenta and umbilical cord through which the embryo feeds and excretes among things till birth.

Changes after birth include:
Changes of proportions: Not all part of the body grow at the same rate and the proportions vary at different ages e.g. the head which is extremely large in the embryo and new born in comparison to the trunk grows less than the trunk after birth and thus forms a progressively smaller proportion of the body.
Changes in rate of the growth: The growth which rate at birth is initially very high but drops quickly during the first few years and levels out to a steady increase each year.
Hardening of the skeleton: The skeleton which mainly consists of cartilage at birth is gradually hardened as the cartilage changes into bone.
Maturation: i.e. attainment of sexual maturity. All these events are under the control of hormones.