Growth and differentiation in plants

Growth is defined as an irreversible increase in dry mass and side of protoplasm.

Growth of a multicellular organism can be divided into three phases:

1. Cell division (hyperplasia) an increase in cell number as a result of mitotic division.
2. Cell expansion (hyper trophy) an irreversible increase in cell size as a result of the uptake of water and assimilation of material leading to the synthesis of the protoplasm;
3. Cell differentiation (specialization of cells); in its broad sense, growth also includes this phase of cell development. The cells do not divide any more. Growth is usually accompanied by an increase in the complexity of the organism by the formation of new tissue and organs. This is known as development.

All the above processes take place at almost the same time. It is difficult to determine where one stops and the other begins.

Measuring growth

Growth can be estimated by measuring some parameter of the organism such as fresh weight, dry weight, height, length, surface area, volume etc. Each has advantages and disadvantages.

One of the disadvantages of measuring growth by changes in size or weight is due to the ignorance of the fact of allometric growth.

Allometric growth is the growth of different parts of the body at rates peculiar to themselves, higher or lower than the growth rate of the body as a whole.

Isometric growth is the growth of different parts of the body at same rate as the growth rate of the body as a whole.

Growth and development in plants.

Primary and secondary meristems

A primary meristem is a region of active cell division that has persisted from its origin in the embryo or young plant. It results in primary tissue. Apical meristems are primary meristems.

A secondary meristem is a region of active cell division that has arisen from permanent tissue. The cork cambium is an example of a secondary meristem.

Apical (primary) growth and differentiation of tissue in the stem

Within the apical meristem are two regions of cells, the outer one is known as the tunica and the inner one the corpus (body). Cell division in the tunica results in growth of the epidermis while that in the corpus results in the growth of the internal tissues.

Cells in the corpus after vacuolation and expansion differentiate to form the parenchyma, collenchyma and sclerenchyma which make up the bulk of the stem i.e. the cortex and pith. Others do not vacuolated and differentiate into procambial strand where the cells retain the ability to divide and then differentiate.

On differentiation these cells form the vascular tissue. Those on the outer side produce protophloem and those on the inside the protoxylem. As new cells are produced by the tunica and corpus they elongate. Further away from the stem apex where the cells are no longer elongating, further differentiation of cells in the procambial strands produces metaphloem and metaxylem.

Near the apex both the tunica and corpus result into the production of leaf primordial at regularly spaced intervals as the stem elongates. It is these that grow into leaves later.

Within the leaf axile is a small axillary bud this produces lateral branches down the stem.

Near the stem apex secretion of auxin by the apical meristem usually prevent such lateral growth resulting in apical dominance.

Distribution of plant tissue along a growing stem.

When the tunica cells divide, the plane of division is such that the new cell walls are always at right angles to the surface and this keeps their arrangement so regular. However, in the corpus the cells divide in several different planes, hence their more haphazard appearance.

If a cell divides parallel to the surface it will broaden the stem apex and if it divide at right angle to the surface (as tunica cells do), it will lengthen it.

Primary growth of the root.

At the very tip of the apical meristem is a quiescent centre, a group of initials from which all other cells in the root can be traced, but whose rate of cell division is much slower than their daughter cells in the apical meristem around them. 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 addition function of acting as gravity sensors, since they contain large starch grains which act as statolith.

A statolith is one of a number of large starch granules that consistently lie on the lower most side of certain plant cells.

Diagram on page 783 biological science fig 8)

The root has a quiescent centre (it has the apical initials) from which all the other cells are formed. It is an area of slow dividing cells in comparison to the cells surrounding it.

Just behind the quiescent centre, the root of shows three meristematic regions same as in a shoot apex.

i) Protoderm-it gives rise to epidermis.

ii) Ground meristem- it gives rise to parenchyma of cortex and endodermis.

iii) Procambium- it gives rise to pericycle, primary phloem and primary xylem and vascular cambium. It also includes pericycle and pith if present.

Calyptrogen area part of the protoderm gives rise to root cap

The root also has region of cell division, cell alongation and cell differentiation. The region of cell division extends to only 1-2 mm for the root.

NB in the shoot apex the tunica is the protoderm and corpus is the ground meristem and procambium.

Secondary growth

Some plants notably conifers and woody dicots last for several years (i.e. they are perennial). Since such plants grow in length each year, their mass increases beyond that which can be supported by their primary tissues alone. They therefore overcome the problem by increasing their girth as their length increase by producing secondary tissues in a process known as secondary thickening or secondary growth.

Secondary growth is the formation of additional secondary, vascular tissue by the activity of the cambium with accompanying increase in the diameter of the stem/root providing additional conducting and supporting tissue for the growing plant.

Secondary growth is brought about by meristematic cells (the cambium) located between the phloem and xylem which have retained the capacity to divide mitotically unlike other cells in the primary stem and root.

Firstly the groups of cambium cells divide radially to form a cylinder or ring of cambium tissue (this is known as thin vascular cambium) separating the xylem from the phloem. The xylem is situated on the inside of the cambium ring and the phloem on the outside.

The cells of the inter fascicular cambium (these cells are also known as fasform initials) divide tangentially to form secondary xylem tissue on inside and secondary phloem on outside. In between adjacent vascular bundles, type of vascular cambium cells known as ray initials form secondary parenchyma there by increasing the girth of the medullary rays.

Similar growth occurs in the stem. The medullary rays are from cambium cells, the rays radiate through the secondary phloem and xylem. They serve to transport water and nutrients between them. Usually more secondary xylem is formed than secondary phloem with the result that the phloem and cambial ring gradually get pushed to the outside forming part of the bark.

The cambium cells divide radially in order to keep pace with its ever increasing circumference.

In temperate region growth is restricted to spring and summer. In tropical and subtropical it is throughout except in those areas which have the dry season.

In the spring the first formed xylem contain a high proportion of large vessels with relatively thin walls to carry the spring flow of the transpiration stream. There is narrowing of the vessels and thickening of their walls as the summer progresses. Also an increasing number of thick-walled sclerenchyma fibres are formed.

The result of this is a harder and denser wood being distinguished from whiter soft spring wood.

The consequence of this seasonal growth is the formation of series of concentric annual rings which can be counted if the stem is severed.

This given an accurate method of estimating the age of trees e.g. counting there annual rage in conifers in California has shown them to be over 3000years.

The increase in girth of the stem strains the surface tissue epidermis and eventually ruptures them hence destroying them.

Fortunately prior to this just beneath the epidermis a layer of cells, called the cork cambium (phellogen), divides tangentially to form new surface tissues. Those cut off on the inside of the cork cambium form the secondary cortex. (phelloderm). Those cut off to the outside form a layer of corky cell.

The three layers the cork cambium, corky cells and secondary cortex are known as the periderm.

The periderm and phloem are commonly referred to as the bark. That is why in ringing experiment translocation of food is inhibited because the bark has to be removed.

The walls of the cork cells are impregnated with suberin, a fatty material which renders them impermeable to water and respiratory gases.

The respiratory gases are exchangeable only at lenticels. A lenticel is a loose mass of cells formed periodically in the corky layer of cells.

The ones near the surface are older, have impermeable walls impregnated with suberin are dead and form the cork.

Draw the diagram showing the arrangement of tissues in a stem after secondary growth. Pg 787 fig 21.28 biological sciences.

Measurement of growth

Sigmoid growth curve.

a) Lag phase (little growth)

b) Log phase (grand period of growth)

c) Inflexion point (there is exponential increase and it's the point where the rate of growth begins to slow down).

d) Decelerating phase (the growth becomes limited as aresult of the effect of some internal or external factor or interaction of both).

e) Plateau phase or stationary phase. (Overall growth has ceased).

And may even become negative as degradation out passes synthesis during the senescence phase that precedes death (negative growth). Such growth curves are typical of many multicellular organism e.g. annual plants, birds, mammals), organ e.g. leaves, and colony of unicellular organism e.g. bacteria, yeast. Some organism never entirely cease growing; they include woody perennials, algae, fungi and many annual (particularly invertebrates, fishes and reptiles)

Intermittent growth in arthropods

The smooth growth curve is typical of most animals but there is an exception in arthropods. If the weight changes of and results are plotted against time, a curve as shown below is obtain instead of increasing smoothly, growth takes place in a series of steps. These correspond to the sequence of steps, or instars, in the insect's development.

Intermittent growth in *Periplaneta americana*

The growth shows the increase in weight of a cockroach. (*Periplaneta americana*) over a period of nearly 2 ½ months. The sudden weight increases (marked by arrows) correspond to moulting of the outside. When moulting occurs this particular insect swallows air thereby expanding the new soft cuticle before it hardens.

The intermittent growth is made necessary by the hard cutide (exo skeleton) which prevents overall growth of the whole body. Periodically the cuticle is shed, and only then can growth take place, while the new cuticle underneath is still soft enough to allow the body to expand. In some cases rapid expansion is achieved by the insect swallowing air or water. The distension of the gut pushes the soft integuments outwards.

The new cuticle then hardens, after which further growth is impossible until the outside is shed again.

The shedding process is known as moulting or ecdysis (discontinuous growth) and it takes place by the secretion of a moulting fluid immediately beneath the cuticle. This dissolves the soft inner part of 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 the chitin a complex nitrogen – containing polysaccharide. Hardening of the outer part is achieved by the chitin being impregnated with tanned (hardened) protein. Water proofing of the cuticle is achieved by the deposition of a thin layer of wax at the surface.

Metamorphosis

Metamorphosis is the change which occurs from the larval to adult form and generally it involves a profound reorganization of the body, often involving considerable breakdown of larval issues.

Hemimetabolous insects like locusts, cockroach, grasshoppers, termites, show incomplete metamorphosis: the egg develops into the adult via a series of nymph which are similar to small adults lacking wings.

Holometabolous insects like butterflies, mosquitoes beetles and flies, show complete metamorphosis

Put down the table 21.4 page 788 Biological sciences

The role of hormones in insect metamorphosis

Insect metamorphosis is regulated by environmental factors which influence hormonal and nervous activity within the insect.

Food availability and certain light and temperature condition influence neuro-secretion cells in the brain to release prothoracicotropic hormone (PTTH) which passes down axom to be stored in pair of glands; the corpus cardiacum (corpora cardiac. The stimulus to moult may vary from species to species but in all cases it causes the release PTTH into the haemocoel. PTTH acts on the further glands, the copora allata one is allatum and the prothoracic glands. The prothoracic secrete a moulting hormone, (MH) called ecdyson, corpus allatum produces another hormone c juvenile hormone or neotonin. The simultaneous release both hormones influences the formation new cuticle from epidermal cells to produce larval or nymph cuticle larval or nymph body form. As metamorphosis ends the amount of ecdysone released falls.

At a critical level of juvenile hormone pupal ecdysis occurs. At the time the next moult no more juvenile hormones.

Dormancy

This is an inactive period in the life of an animal or plant during which growth slows or completely ceases. Physiological changes associated with dormancy help the organism survive adverse environmental conditions.

Annual plants survive the winter as dormant seeds while many perennial plants survive as dormant tubers, rhizomes, corms or bulbs.

Hibernation and aestivation are forms of dormancy in animal that helps them survive extreme of cold and heat, respectively. In these states there is lowering of body temperature slowing down of feedings, respiration, movement and other body activities.

Seed dormancy

Seed dormancy is when a viable seed fails to germinate even when all conditions necessary for germination are provided and in this state its metabolic activity is greatly reduced as its moisture content is very low.

Causes of seed dormancy

i) Seed coat.
The seed coat is hard and impermeable and prevents the entry of water and oxygen.

ii) Growth anhibitors.
Same seeds may contain growth inhibitors abscisic acid, coumarin, phenolic acids, short chain acids in the embryo, endosperm or other tissues also prevent germination.

iii) Specific light requirements. In certain seeds, dormancy can be brought about by lack of red light e.g. in lettuce plants. Certain seeds remain dormant as long as exposed to light e.g. phacelia and Nigella.

iv) Temperature.
Some seeds require a cold period or stratification before germination e.g. cereals and Roses. It brings a rise in gibberellins level.

v) Immature of the embryo
When the embryo is immature, its unable to synthesize gibberellins

vi) Lack of water, oxygen and a suitable temperature. Water is required to activate biochemical reaction like digestion of food reserves after imbibition e.g. Starch **amylase** to maltose **maltase** to glucose.
Proteins **protease** to amino acids
Oxygen is needed for aerobic respiration; suitable temperature influences the rates of enzyme controlled reaction.

Methods to break seed dormancy

i) Weaken the seed coat by soaking in water and dilute acid, artificially remove the testa.
ii) Apply growth promoters such as gibberellins and cytokinins.
iii) Expose the seeds to their optimum light requirements.
iv) Expose the seeds to their optimum temperature requirements.
v) Allow seeds to undergo after ripening period to allow the embryo to mature.
vi) Provide water, oxygen and the right temperature.

Advantages of dormancy

- It ensures that seed germinates under suitable conditions.
- It allows time for seed dispersal.
- Enables a plant survive adverse conditions.
- Seeds can be stored for a long time.

Seed Germination

Germination is the development of the embryo of a seed into a seedling.

Conditions necessary for seed formation

i) Water
ii) Oxygen
iii) Optimum temperature

Water: Most seeds germinate after taking water. The initial uptake of water by the dehydrated seed is called imbibition. It is caused by absorption of water by the molecules of the cell and as a result the seed begin to swell.

Imbibition is caused by rehydration of structure molecules like hemicelluloses and pectin and storage molecules like proteins and starch. The imbibition forces are so strong that they rupture the seed coat. As the water moves into the cell, metabolic activities are restored.

Optimum temperature and Oxygen reasons already given

Effect of light reason already given into specific light requirement for germination can be substituted by gibberellius and cytokeuos

Kinds of germination

Epigeal and Hypogeal-reserve their definitation

Mobilization of reserves during seed germination.

Food material is stored in the form of carbohydrates, lipids and protein in a seed. In some, it is stored in the endosperm while others store it in the cotyledon of the embryo. The food stored is insoluble in water and needs to be broken down to simple water soluble substance so that it can be transported to the embryo for growth.

During seed germination as the seed absorbs water, embryo gets activiated and secrete gibberellin. The activities begin both at the storage centre (food reserve) and at the growth centre (embryo)

Sequences of events that follow seed germination are as given below.

i. Imbibitions of water by seed.
ii. Activation of embryo which secretes gibberellien
iii. Diffusion of gibberellium to the aleurone layer
iv. Synthesis of α-amylase and many other enzymes in the aleurone layer. Activation of respiratory enzymes already present.
v. Diffusion of hydrolyzing enzymes from aleurone layer to the food storage region (endosperm or cotyledon)
vi. Break down of food reserves by hydrolytic enzymes into water soluble products in the storage centre.
   Protein $\xrightarrow{\textbf{protease}}$ Amino acid
   Starch $\xrightarrow{\textbf{amylase}}$ sugar like gluscose
   Lipids $\xrightarrow{\textbf{lipase}}$ fatty acid +glycerol

vii. Translocation of products of digestion like sugars, fatty acids and glycerol to the embryo via the cotyledon

viii. Utilization of these substances for respiration as well as for synthesis of other substances required for embryonic growth.
I.e Abscissic acid-ABA works antagonistic to gibberellins. ABA induces seed dormancy while gibberellins break it
Seed viviparity-- this is the germination of the seed while it is still attached to parent plant and nourished by it.

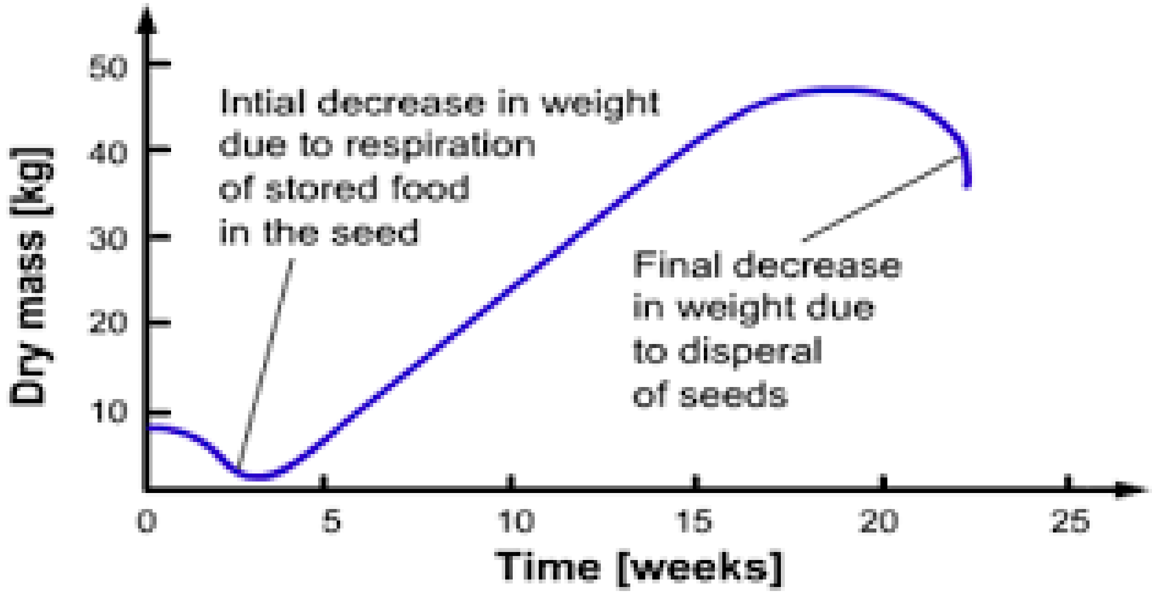
Development in vertebrates

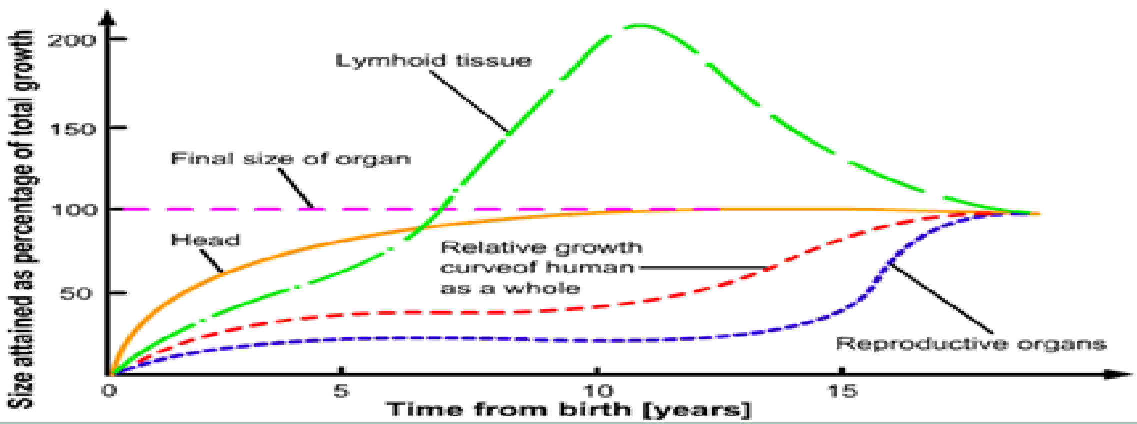
The development of the zygote until the time of hatching or birth is a continuous process though can be divided into three stages

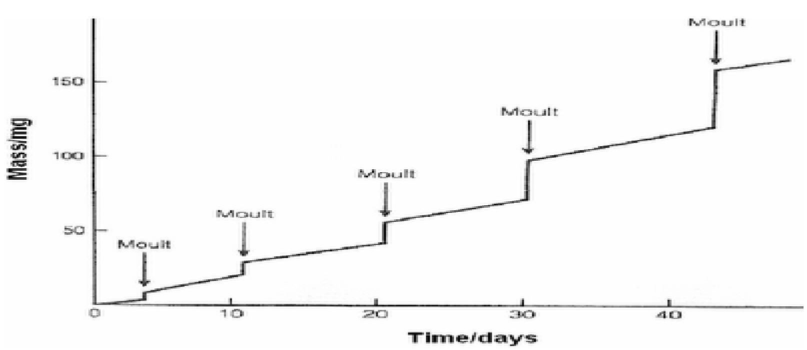
Cleavage, gastrulation and organogeny

i. Cleavage is a series of mitotic division of the zygote after fertilization producing daughter cells called blastomeres forming a hallow ball of cells called blastula which enclose a cavity called blastocoel. Cleavage increase the nuclear cytoplasmic ratio and therefore increase nuclear control over the cytoplasmic
ii. Gastrulation involves the re-arrangement of cells into new position and establish the axes of the embryo and now the cells are distinct as three `primary germ layers, I.e the ectoderm, mesoderm and endosperm. (A blastopore (circular opening) appears at the onset of gastrulation) i.e there is Invagination which is the infolding of cell sheet into embryo, forming the mouth, anus and archenteron

iii. Organogeny occurs next leading to production of definite tissues.
Hear further cell division, growth and differentiation occurs involving many complex morphogenic activities including the formation of the notochord, central nervous system and development of the mesoderm. This gives rise to tissues, organs and organ system of the embryo. Organogenesis is terminated by hatching or birth of the young individual.
The whole development process is regulated the by hormones secreted by the thyroid, liver, adrenal context and growth these glands are themselves under the influences of other hormones released for the totipotency


Dry mass [kg]
50
40
30
20
10
Intial decrease in weight
due to respiration
of stored food
in the seed
Final decrease
in weight due
to disperal
of seeds
0
5
10
15
20
25
Time [weeks]


Size attained as percentage of total growth
200
150
100
50
Lymhoid tissue
Final size of organ
Head
Relative growth
curveof human
as a whole
Reproductive organs
0
5
10
15
Time from birth [years]


Mass/mg
150
100
50
Moult
Moult
Moult
Moult
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Moult
0
10
20
30
40
Time/days