UNIT 16 PLANT HORMONES

Structure

16.1 INTRODUCTION

In the previous Units 11 to 15 you have learnt about nutrition in plants. In this unit and the one that follows we will deal with control of plant growth and development.

You may have often wondered why in a germinating seedling, roots grow in downward direction whereas shoots grow upwards. Why some flowers bloom during the day, but close at night, as if to sleep. Why one rotten apple in a basket leads to rotting of others or what causes leaf fall? How are the processes of cell division and cell elongation controlled? These are some of the questions, amongst many others, which do not have any simple answers, for most of these phenomena are controlled by complicated interactions among three levels of controls—genetic, hormonal and environmental. The various genes in a species are turned on at precise times to control cell activity and various characteristics of organisms. One class of potent chemicals that coordinate growth and development in plants and animals are hormones. They trigger cellular reactions in target cells and also determine the genes that are to be expressed at a particular stage of development. Environmental factors such as light and temperature also affect and control growth and development. These will be dealt with in the following unit.

In this unit we will tell you about different groups of plant hormones, how they were discovered and the various roles they play in growth and development of plants. Finally we will also discuss the application of plant hormones in agriculture.

Objectives

After studying this unit you should be able to:

- explain the experiments that led to the discovery of auxins,
- describe the discovery of gibberellins,
- describe the experimental technique of Went used for the bioassay of auxins,
- list the five groups of plant hormones, their site of production and their role in plant growth and development,
- discuss the possible mechanism of action of plant hormones,
- describe commercial applications of plant hormones.

16.2 DISCOVERY AND CHARACTERISTICS OF PLANT HORMONES

To date, five major classes of plant hormones have been discovered namely auxins, gibberellins, cytokinins, abscisic acid and ethylene. It is possible that many other growth regulators, present in plants, may be classified as plant hormone in the future. Not all plant hormones fit the general definition of a hormone which is a chemical synthesised in one part of an organism that stimulates or inhibits a specific response in a target tissue elsewhere in the organism.

The five groups of natural hormones—auxins, gibberellins, cytokinins, ethylene and abscisic acid fit the classical definition of hormones. Synthetic chemicals used as hormones are referred to as **plant growth regulators.**

Most animal hormones trigger highly specific responses in the target tissue. But the responses of plant hormones are quite different compared to that of animal hormones. The following are the important features of the role of plant hormones in growth and development.

i) The hormone may initiate one response in one part of the plant and an entirely different response in another part.
ii) Quite often interaction of various hormones may elicit an expected or different response from what each hormone will individually produce. They may work synergistically or antagonistically.
iii) The effect of a hormone may even vary with concentration, during different times of the year or the developmental stages of the plant.

These variables make it difficult to answer specific questions on the role of plant hormones in growth and development. Thus this area is one of the most challenging areas of physiology.

16.2.1 Auxins

The history of discovery of auxin is a fascinating chapter in plant physiology. The hormone auxin was discovered first, through some elegant experiments by Charles Darwin and his son Francis around 1880. They found that if a coleoptile of a grass (*Phalaris*) was illuminated from one side it bends towards light. However, if the tip region was covered, no bending occurred (Fig. 16.1). In his book "The Power of Movement in Plants" published in 1880, Darwin wrote that some matter in the upper part, which is acted upon by light, transmits its effect to the lower part causing the latter to bend.

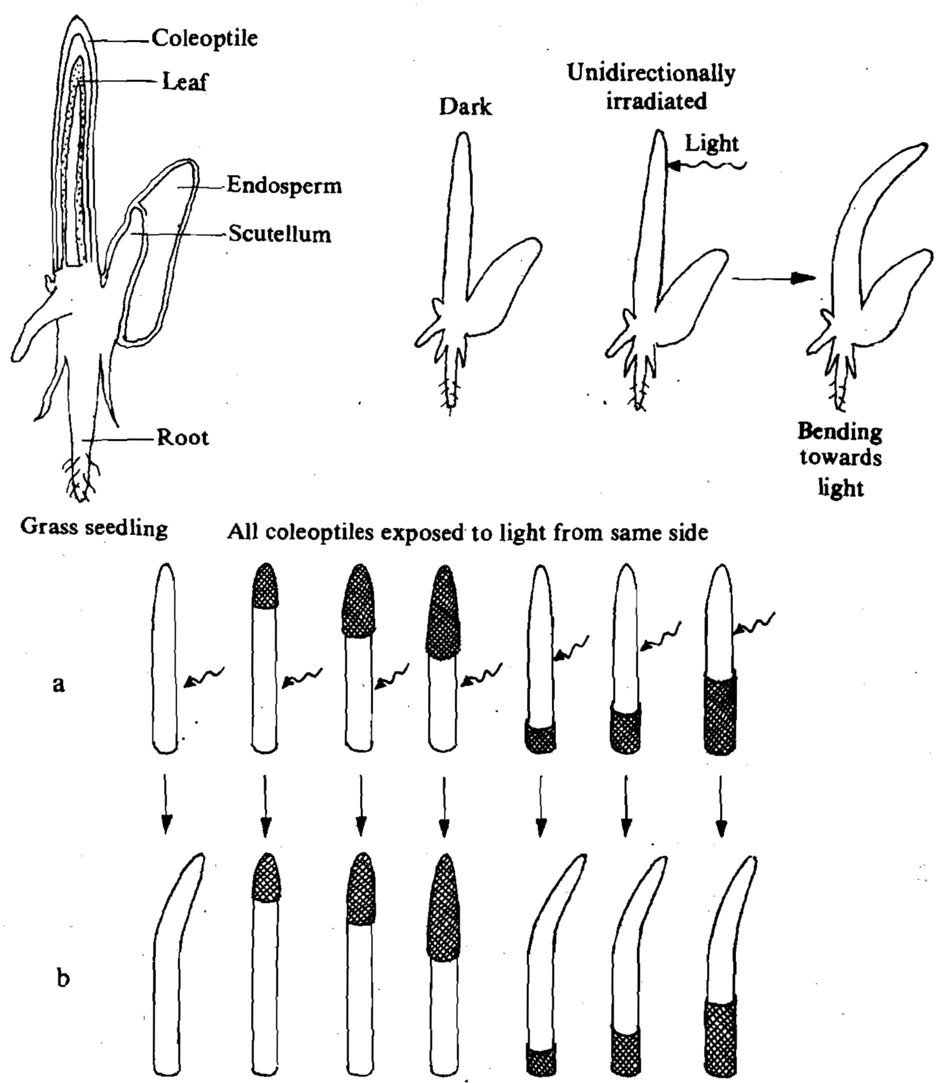


Fig. 16.1: Darwin's experiment on canary grass coleoptiles: a) Various parts were covered with metal caps for the determination of photosensitive region: b) Results observed in each case.

Peter Boysen-Jensen, a Dane and A. Paal a Hungarian did further experiments (Fig. 16.2) on Darwin's observation in order to understand the movement of the stimulus. They decapitated a coleoptile of oat seedlings and in one experiment (a) introduced a tiny gelatin block between the stump and cut tip and in other (b) a thin sheet of mica. The curvature in coleoptile occurred in a but not in b because the stimulus could pass down through gelatin but not through mica. However, when the mica was inserted half way either on lighted side or on darkside the curvature occurred only when the mica was on the lighted side. These observations suggested that the stimulus promotes elongation on dark side. A. Paal observed that in the dark whichever side the cut tip was placed bending occurred in the opposite direction, suggesting that the stimulus in the tip affects cells directly below. This stimulus was later found to be a diffusible substance by a Dutch scientist F.W. Went in 1926. He collected this substance in large amounts by placing decapitated coleoptile tips on agar blocks. He

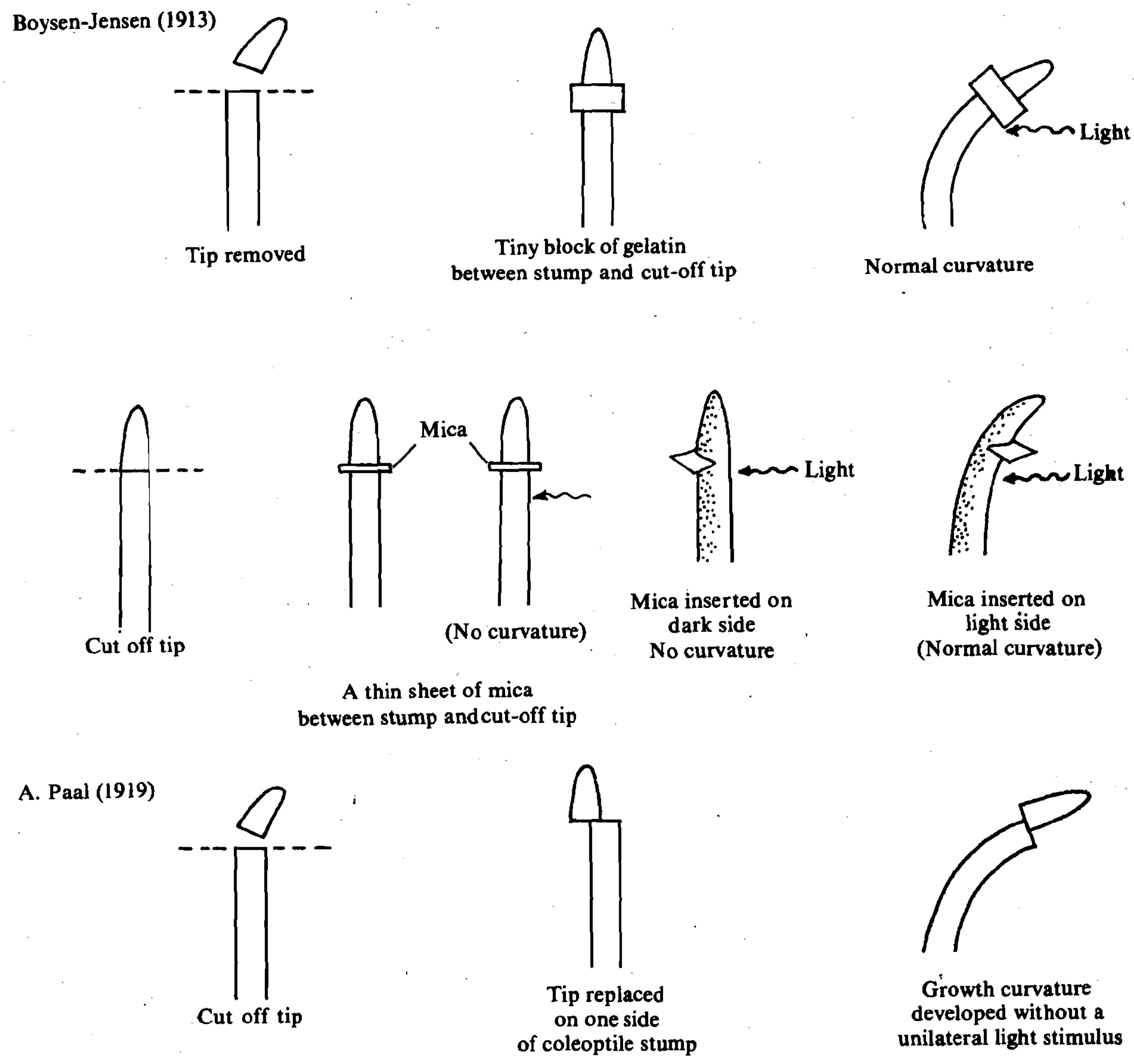


Fig. 16.2: Inserted between stump and the cut-off tip: a) a tiny block of gelatin, b) a thin sheet of mica. Note that on illumination the curvature of the tip of coleoptile was seen in a but not in b. c) displaced tips cause bending in the opposite direction.

then took tiny squares of the agar and placed them eccentrically on the cut end of the decapitated seedlings. Typically bending occurred within an hour after the blocks were applied (Fig. 16.3). He concluded that the substance, present in agar block when placed eccentrically on the coleoptile stump diffused in the coleoptile causing elongation of cells in that side resulting in curvature. Went named it auxin (from the Greek word auxein, "to increase"). Later auxin was chemically characterised as indole-3-acetic acid or IAA (Fig. 16.4).

Went's experiment (1928)

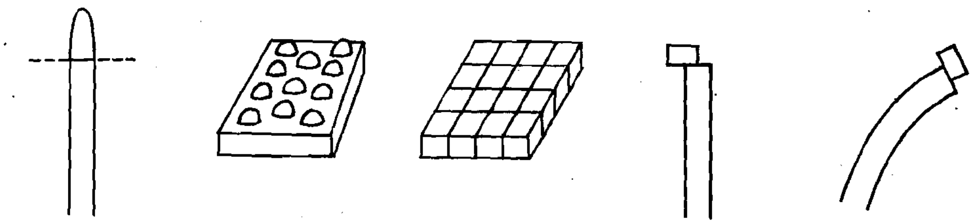


Fig. 16.3: Went's experiment on auxins: a) Collection of difusible substance from the tips of oat coleoptiles on agar blocks. b) The agar blocks placed eccentrically on the coleoptile's cut edge alongside the growing shoot. The curvature is seen on the opposite side.

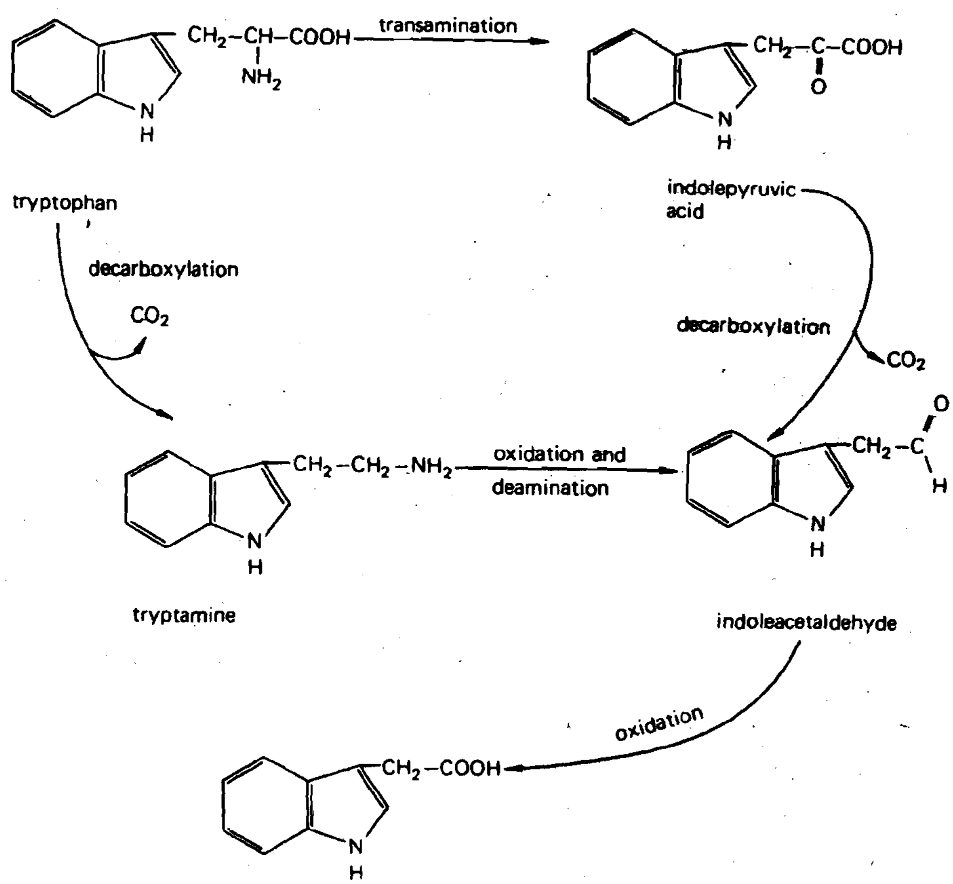


Fig. 16.4: The structure of auxin-indoleacetic acid (IAA) and the probable scheme of its biosynthesis from tryptophan.

Auxins are produced in the growing regions of stems and young leaves. Little did people realise when it was discovered about the tremendous impact it will have in agriculture and horticulture. The presence of auxin can be demonstrated and in fact quantified by a sensitive assay system, known as bioassay, based on Went's basic method as shown in the Fig. 16.5. Hormone concentrations are calculated by the degree of bending seen in the oat coleoptile. The greater the angle, the more the hormone present.

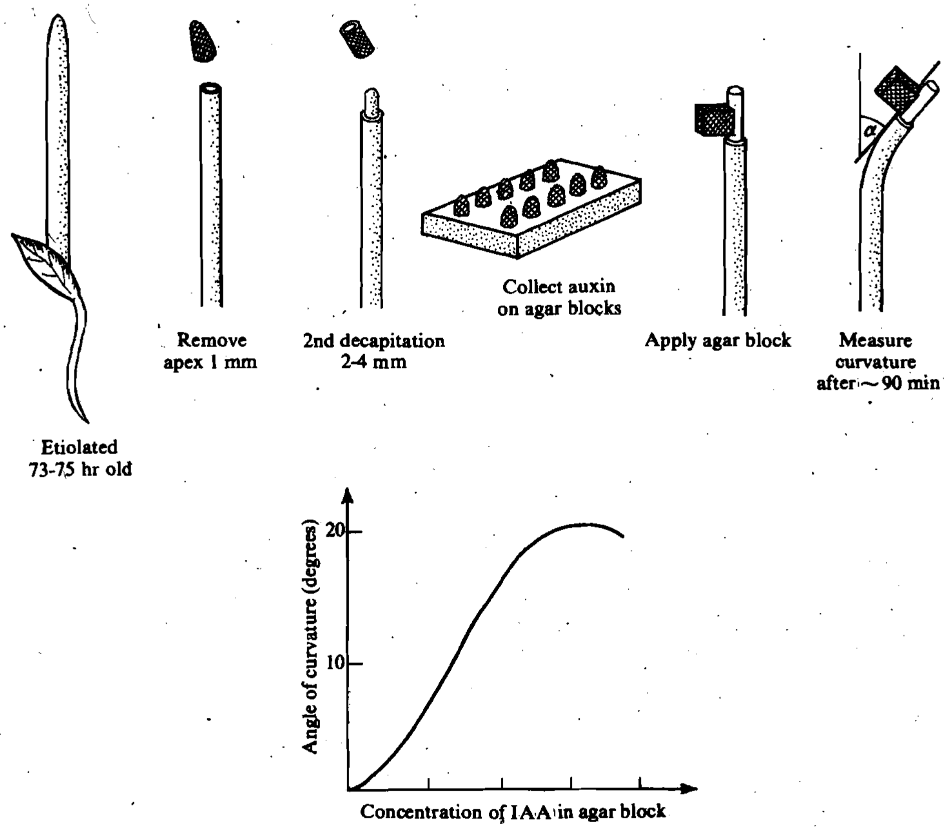


Fig. 16.5: Bioassay of auxin. The extent of bending as measured by the angle α, is a function of the amount of auxin or IAA present in the agar block. (Source, Leopold 1955).

The effect of auxin on growth of roots, stems and buds varies. Roots are the most sensitive, followed by stems and buds which can tolerate a much higher dose of auxin. Look at Fig. 16.6, the concentration of auxin that promotes growth in buds or stems actually inhibits growth of roots. If the concentration of auxin is more than the requirement (optimum concentration), it will inhibit growth. Auxin does not cause growth by division but rather promotes cell enlargement through elongation (Fig. 16.7)

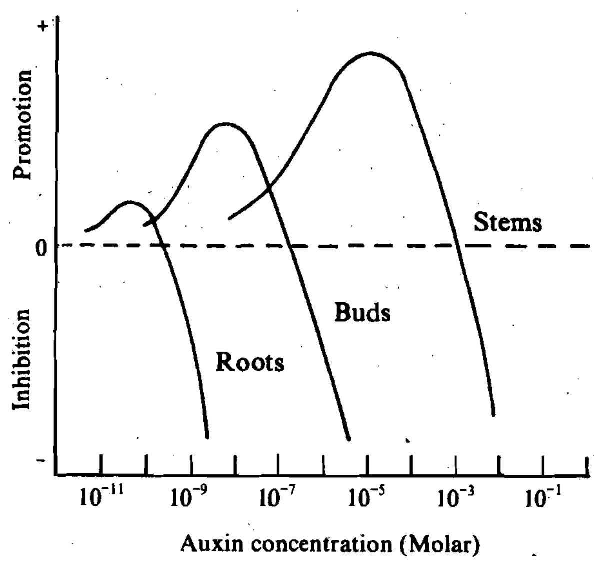


Fig. 16.6: Effect of various doses of auxin on roots, buds and stems. A biphasic dose-response curve is obtained for different plant organs. (Source: Leopold).

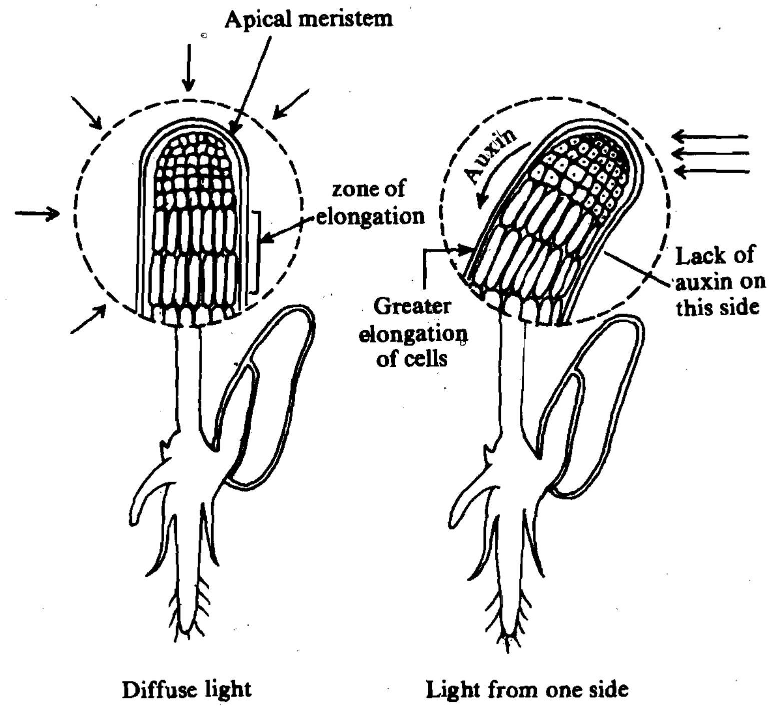


Fig. 16.7: Action of auxins: Cell elongation is promoted by auxin (a) multidirectional light (b) light from one side.

Use of radioactive label technique has shown that IAA is synthesised from tryptophan by the scheme shown in Fig. 16.4. Auxins are synthesised mainly in the shoot apex, young leaves and buds and are transported downward in stems. They promote root initiation and the formation of lateral and adventitious roots, formation and differentiation of secondary vascular tissues, fruits and flower development. Another interesting effect of auxin is apical dominance, where the apical bud exerts an inhibitory effect on the development of the lateral buds. The IAA produced in the apical meristems moves down the stem and inhibits auxillary buds from growing into new leafy stem. If the apical bud is excised then lateral buds develop into sprawling leafy branches. (The same effect is observed if IAA is applied to the cut tips of growing apical buds.) This knowledge is employed by gardeners to make a neat and trim hedge or let a plant acquire a stately appearance. Synthetic auxins are now manufactured commercially. Although chemically different, they show the same effect as the natural auxins produced by the plant. Synthetic auxins are commonly used for mimicking IAA effects. The two commonly employed in laboratories are:

i) naphthalene acetic acid (NAA) and
ii) 2,4-dichlorophenoxy-acetic acid (2,4-D) (Fig. 16.8).

Nearly 9000 kg of oat meristems (a centre for IAA production) were required for the isolation of 1 g of IAA

Synthetic auxins are preferred for experimental work in laboratories because the isolation of natural auxins is tedious and therefore are more expensive. Moreover, unlike IAA, they are destroyed very slowly by plant tissues, and therefore are more stable.

Napthalene acetic acid

2, 4-D

Fig. 16.8: The structure of naphthalene acetic acid (NAA) and 2,4-dichlorophenoxy-acetic acid (2,4-D).

16.2.2 Gibberellins

The gibberellin story actually began in the last decade of the nineteenth century. In 1889, Konishi, a semiliterate Japanese farmer described a disease in rice, known as 'bakanae' (foolish seedling). The characteristic symptom is the appearance of spindly plants which grow so tall that they kneel over and die. Later the causal fungus for the disease was identified as *Gibberella fujikuroi* in 1926. The name gibberellin was assigned to the active factor in *G. fujikuroi* culture filterates in 1935. In 1938 two crystalline biologically active substances named gibberellin A and B were isolated. Today some 72 forms (designated as GA to GA_{72} rather than individually named) have been identified. However, not all of them are active. All gibberellins are diterpenoid acids which have the same basic *ent* gibberellane ring structure (Fig. 16.9) but, vary slightly in their structures depending upon the source from which they are isolated. Some type of gibberellins have been identified in *Gibberella,* and other in higher plants and in many plants both are present. Like *Gibberella* individual angiosperms may contain many different GAs, for instance at least 20 GAs in seeds of the cucurbit and 16 known GAs in seeds of *Phaseolus* species have been identified.

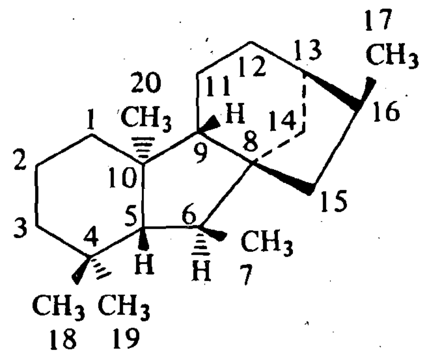


Fig. 16.9: Structural formula of *ent-gibberellane*.

Gibberellins are produced in young leaves around the growing tips, and possibly in roots of some plants. Although their role in root activity is not known.

2-Chloro ethyl trimethyl-ammonium chloride (CCC) blocks the synthesis of gibberellic acid in otherwise normal variety of crop

The effect of GA is dramatically illustrated in genetic dwarf pea or maize where its application to young seedlings, induces them to grow to normal height (Fig. 16.10).

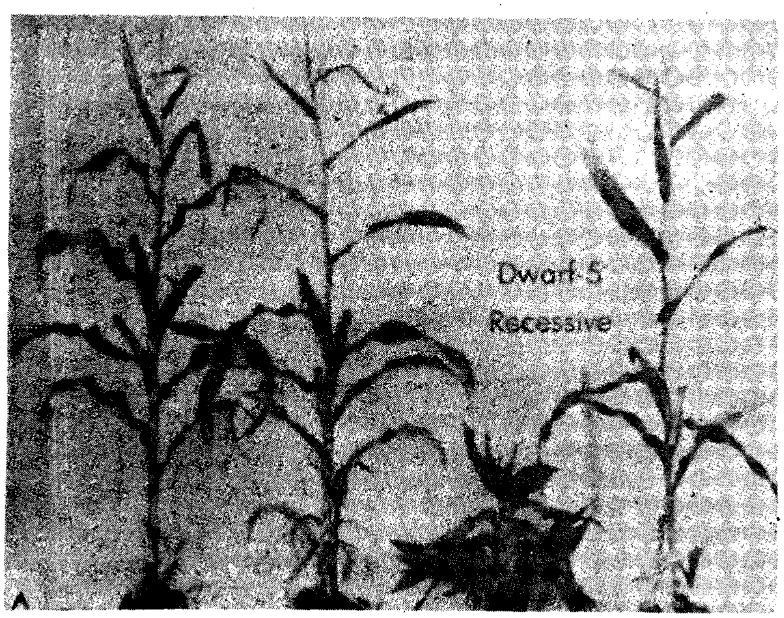


Fig. 16.10: The effect of gibberellic acid (GA_3) on normal and dwarf corn.

This illustrates that the dwarf characteristic is due to a block in the synthesis of gibberellins. GA also stimulates the production of numerous enzymes, notably α-amylase in germinating cereal grains. As these grains germinate the embryo secretes gibberellins which traverse to the aleurone layer that surrounds the starchy endosperm (Fig. 16.11), and stimulate the production of α-amylase which in turn breaks down starch to sugar and makes it available to the growing embryo.

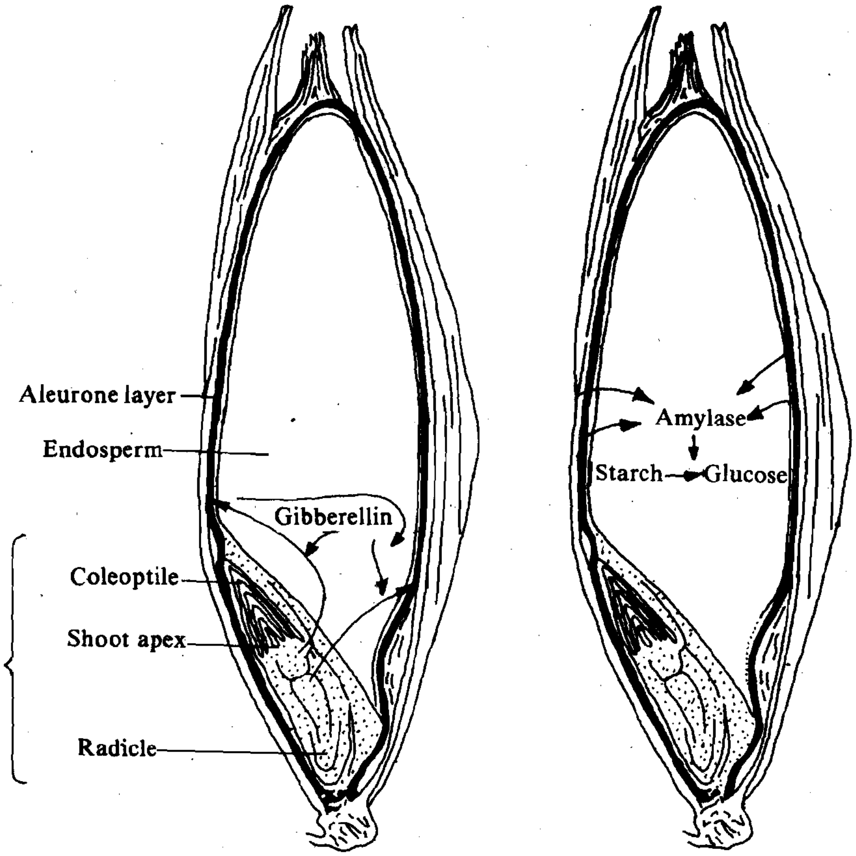


Fig. 16.11 : Gibberellins secreted by embryo moves to the aleurone layer and stimulate the production of α-amylayse.

There are many other interesting effects of gibberellins. For instance, they can induce bolting in long day plants, cause stem elongation (it is however, unable to induce curvature in *Avena* coleoptile if applied asymmetrically on cut stump of the coleoptile) and induce germination in seeds that normally require cold or light treatment to germinate.

16.2.3 Cytokinins

Both auxins and gibberellins mostly affect growth by stimulating elongation of cells. Therefore, there was a frantic search for specific substance which would induce division of cells. Ultimately cytokinin was discovered during the course of investigations dealing with growth of tissues *in vitro* in the 1950s. A substance called kinetin (6-furfurylamino purine) from an autoclaved sample of herring sperm DNA was demonstrated to be very active in promoting mitosis and cell division in excised pith tissue of tobacco grown on a synthetic medium along with auxin. It stimulated shoot formation if the concentration of kinetin employed was higher than that of auxin and root formation when auxin concentration was higher than kinetin (Fig. 16.12). Thus for the first time a clear picture emerged of the role of interaction of hormones on organogenesis and gave a serious blow to the earlier theory that there are different kinds of hormones present in plants which controlled formation of root, stem and leaf.

Unlike auxins and gibberellins, kinetin the first cytokinin (a name proposed to designate all compounds which promote cell division), was never found in plant tissues, although other natural cytokinins were subsequently extracted from plant tissues. In 1964, the first natural cytokinin, zeatin (Fig. 16.12), was described from maize seeds. Since then three others have been identified. Cytokinins are formed in root tips. In addition to root sites, described above, it has recently been demonstrated that biosynthetic sites of cytokinin are also located in the shoot. Studies on seeds of *zeamays* and fruits of tomato, pea and bean indicate that cytokinins are also produced in them.

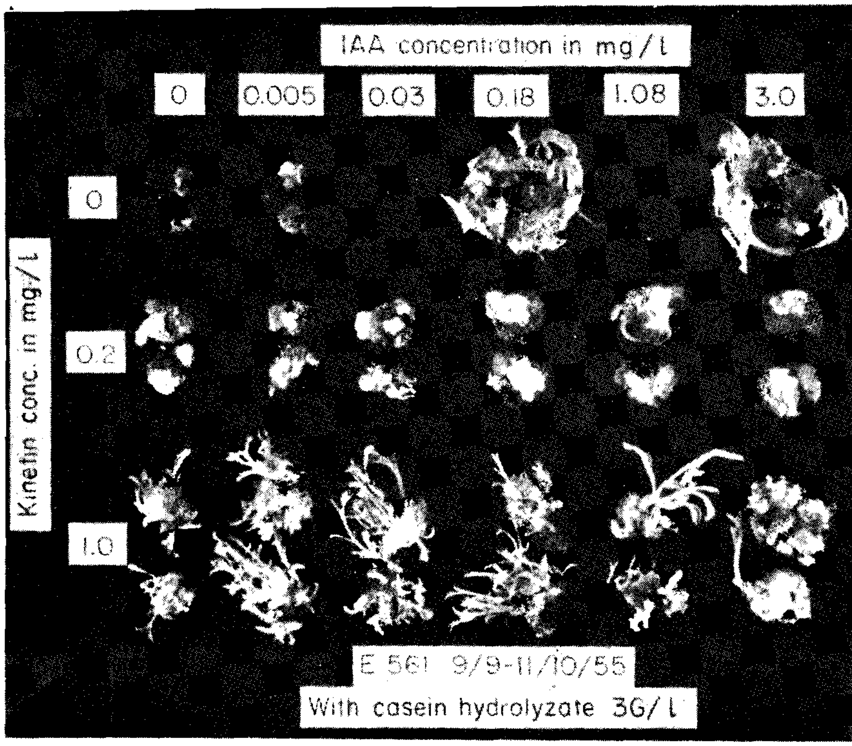


Fig. 16.12: Interaction of hormones in organogenesis. Pith tissue taken from tobacco stem is treated with varying concentration of auxin and cytokinin. (From Skoog and Miller 1957).

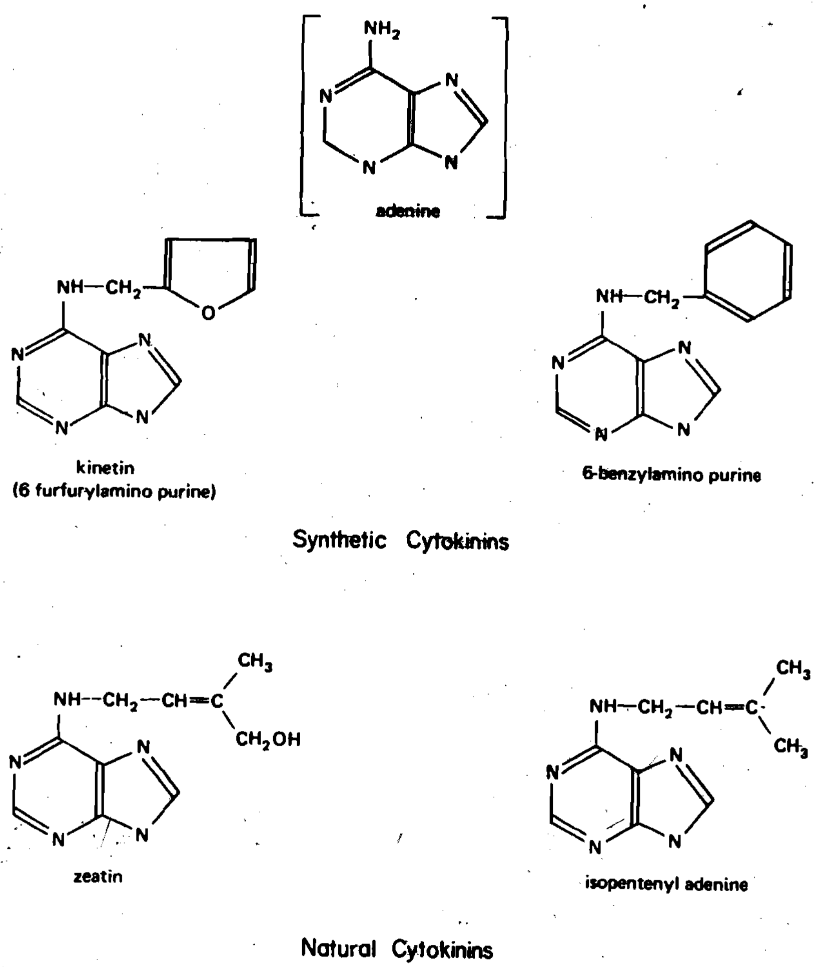


Fig. 16.13: Structure of kinetin and zeatin.

Besides induction of shoots in tissue culture, another effect of cytokinin is associated with senescence or aging in plants. If leaves are treated with cytokinins, aging is retarded, the chlorophyll does not disintegrate and the leaves stay green. Synthetic cytokinins have been applied to harvested vegetable crops such as celery, broccoli and other leafy vegetables to extend their shelf life.

16.2.4 Ethylene

Amongst hormones in both plant and animal kingdoms, ethylene, a gaseous hydrocarbon, is unique. Despite its chemical simplicity, it is a potent growth regulator. Even twenty years ago, there was a dispute whether this gas, which had been shown to have a range of multiple effects on plant tissues could be properly called a hormone. Ethylene can be smelt in ripening fruits, as it is involved in the ripening process. Ethylene gas hastens fruit ripening, and as fruit ripens, it produces even more ethylene gas. It is production of ethylene gas by overripe fruits that explains why one rotten apple can spoil the whole basket. Stimulation of fruit ripening by ethylene has been commercially exploited by shipping tomatoes, bananas, oranges, mangoes and many other fruits when green, in ventilated crates (to prevent accumulation of ethylene) and then gased with ethylene before distributing to consumer.

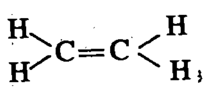


Fig. 16.14: Ethylene

Ethylene may also help in determining sex in certain flowers. Along with gibberellin ethylene controls the ratio of male to female flowers. Ethylene treatment ensures higher ratio of female flowers in some monoecious plants such as cucumber. Therefore, ethylene is widely used in green houses to increase the yield of cucumber by inducing the production of female flowers. Silver nitrate is an antagonist of ethylene. It induces the formation of male flowers.

16.2.5 Abscisic Acid

Abscisic acid (ABA) as a naturally occurring growth inhibitor was discovered through independent investigations of different physiological phenomena in two different laboratories. F.T. Addicott and collaborators (University of California) had been investigating natural substances which accelerate leaf abscission, whereas P.F. Wareing et al (University College of Wales at Aberystwyth) had been investigating natural inhibitors which appeared to be related to bud dormancy in woody plants. By 1965, these two paths of research converged upon the discovery that a single hormone was involved in both. The term abscisic acid (ABA), was later proposed to denote this compound, which is a sesquiterpenoid (15-C) compound (Fig. 16.15).

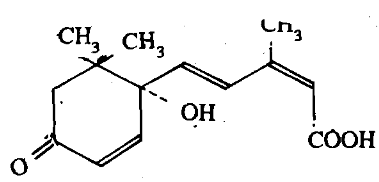


Fig. 16.15: Structure of Abscisic Acid.

Abscisic acid (ABA) is a particularly interesting hormone with regard to the regulation of its own levels. Its levels rise and fall dramatically in several kinds of tissues in response to environmental and developmental changes. Following are the roles of abscisic acid:

i) When leaves of mesophytic plants are water stressed (i.e. under water shortage condition) ABA levels can rise from 10 to 50-fold within 4-8 hours. When the plants are rewatered, the ABA levels drop dramatically within 4-8 hours.
ii) It is generally believed that abscisic acid induces dormancy in seeds to tide over adverse environmental conditions such as freezing temperature or stresses of hot dry periods causing water shortage. Dormancy is induced also in deciduous plants.
iii) You have already learnt that when abscisic acid accumulates in guard cells during periods of water shortage, it causes stomates to close thus enabling the plants to recover water balance.

iv) The name abscisic acid was originally proposed as early investigators believed that it caused flowers, fruits and leaves to abscise (fall). However, now there is dispute over whether ABA is involved at all in the abscission process.

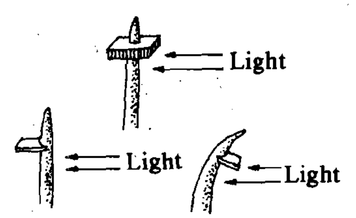
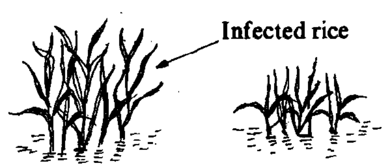
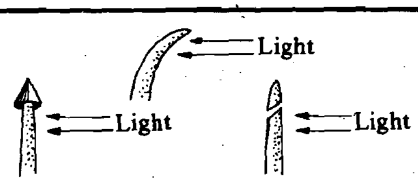
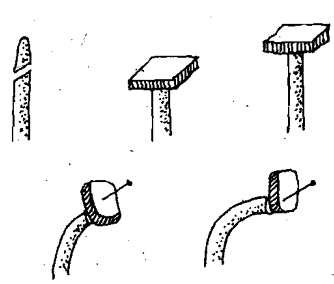
16.3 OTHER GROWTH REGULATORS

Besides the major five hormones, polyamines can also exert regulatory control over growth and development at micromolar concentrations. They are widespread and probably occur in all cells. However, there is some controversy as to whether polyamines should be classified as hormones.

Polyamines have a wide range of effects on plant development. It appears polyamines are present in all cells and are not confined to the specific site where they are synthesised. Whether polyamines are classified as plant hormones or not is immaterial as they definitely control plant growth and development to a great extent and are therefore, major plant growth regulators.

SAQ 1

a) Match the scientists given in Column 1 with their experiments illustrated diagrammatically in Column 2.

Column 1	Column 2
i) Darwin 1880	
ii) Boysen-Jensen 1910	
iii) F. Went 1926	
iv) E. Kurosawa 1926	

b) In the following statements choose the appropriate word given in parenthesis so as to make the statement correct.

i) (Gibberellins/Abscisic acid) inhibit cell elongation and cell division.

ii) (Cytokinins/Auxins) promote cell division.

iii) (Auxins/Gibberellins) promote root formation, and (cytokinins/auxins) remove apical dominance.

iv) (Gibberellins/Cytokinins) restore normal growth in dwarfs.

v) (Abscisic acid/Cytokinins) retard senescence or aging while (abscisic acid/ cytokinins) may cause leaf abscission.

c) Match the hormones listed in Column 1 with its functions listed in Column 2.

Hormone	Function(s)
i) Auxins (IAA)	a) Delays senescence
ii) Gibberellins	b) Promotes dormancy and stomate closure
iii) Cytokinins	c) Root development
iv) Ethylene gas	d) Stimulates aleurone layer to produce starch-digesting enzyme
v) Abscisic acid	e) Promotes fruit ripening

d) Draw a small plant and indicate in which of the parts auxins, cytokinins, and gibberellins are mainly synthesised.

16.4 HOW DO HORMONES ACT?

All plant hormones show extraordinary varied complex effects in controlling plant growth and development, Extrapolation from how an animal hormone works, a common framework for different plant hormones may explain their varied effects. In animals, the wide variety of effects shown by different hormones are understood by the mechanism of action at the cell level. You may recall that the target cells have appropriate receptors for hormones either on the plasma membrane or are located generally in the interior of the cell. Similar attempts have been made to explain the mechanism of action of plant hormones employing the receptor concept. Both natural and synthetic hormones behave in a similar way as it is assumed that they bind to specific receptors to form a hormone receptor complex to trigger an effect.

Though search for a receptor protein has been generally a frustrating one, recently, such proteins have been demonstrated in pea which bind with auxins before eliciting a response such as embryoid differentiation in tissue culture.

Cell elongation, the most well-known response of auxin, requires that the longitudinal wall stretches, which will involve basic changes in cell wall. In order to stretch, cell wall has to become more plastic, just like a balloon, in which the driving force to increase the volume is proportional to the resistance offered by the balloon wall. Increased plasticity of the cell wall by auxin is considered to be due to breaking of some of the bonds between the polysaccharide components of the cell wall. As it becomes plastic the cell is amenable to stretching.

The structure of gibberellin resembles certain animal steroid neurotransmitters. The search for gibberellin receptor in cytoplasm rather than in the membrane has not been fruitful unlike animal neurotransmitters which bind to cytoplasmic receptors.

Though the biochemical mode of action of plant hormones is poorly understood, still the general assumption in current research work is that plant cells have specific receptors which when bound to hormones activate the signal transduction pathway for various activities. However, though many proteins have been found by various workers to bind with hormones, these may be inactive complexes. Currently search is on to identify the nature of the receptor and decipher its mode of action.

16.5 APPLICATION OF PLANT HORMONES

Unknown to the farmer plant hormones were already playing an important role in agriculture and horticulture even prior to their identification. For example, in order to synchronise flowering in mango or pineapple, fires were lit adjacent to fields in which these crops were grown, although the reason was not known at that time. The ethylene generated as a result of incomplete combustion stimulated flowering. The same treatment was followed to stimulate ripening in lemons. Use of ethylene for effective transport of fruits has already been described. Green fruits are preferred during transport which are ripened by treating with ethylene whenever desired.

One major application of synthetic auxins has been in controlling weeds. One such compound is 2, 4-D, which promotes growth at very low concentration whereas it kills plants at high concentrations. Broad leaved plants are more sensitive to this herbicide than narrow leaved ones. This is the basis of killing weeds (generally dicots) in wheat, rice or oat fields.

Weed control agents (herbicides or weedicides) can be very dangerous too. For example, there has been serious questions about the biological effects of 2, 4, 5.T (2, 4, 5, trichloroacetic acid) which was used as weedicide during the Vietnam war. In laboratories, it was found to cause birth defects in mammals, (mice and rats) when treated during early pregnancy. This report along with reports of increased occurrence of human birth defects among South Vietnamese population in 1969 prompted strong protests against its use. However, later the harmful effects were attributed to dioxin, the infamous environmental pollutant, which contaminated 2, 4, 5.T during its production.

Plant hormones have also found practical application in rooting of cuttings, parthenocarpic fruit set, thinning of fruit trees, inhibiting sprouting in cereal grains and potatoes, inhibiting bud growth, inducing flowering, defoliation, and preventing preharvest fruit drop. All of these uses involve auxins, except the induction of flowering in pineapple which can be done with acetylene.

There is a world wide attempt to develop commercial plant growth regulators which will be able to increase basic productivity or yield of a crop such as wheat, rice or peas. However, this has not yet been achieved as the task seems to be too complex to be accomplished. One has to first identify the right crop, the hormone to be applied at the proper concentration at the right stage of development, and then develop a criterion to measure the increase in yield. Success in promoting yields has always occurred when a specific goal is recognised such as increase in sugar content of sugar cane (by gibberellic acid which causes increase in stalk elongation when flowering prevented. This resulted in the increase of sugar content), promote flow of latex in *Hevea* and prevent lodging of small grains.

Finally it is a fact that applications of plant hormones have found use mainly in horticultural crops, as a result of repeated empirical tests by various workers. The range of application can be extended only with clear understanding of regulation of plant growth and development by natural plant hormones and synthetic growth regulators. Time is not yet ripe to put this knowledge to practical use in the case of agricultural crops.

SAQ 2

Which of the growth regulators you will apply for the commercial purposes listed in column 1.

Commercial Application	Growth Regulator
i) Control of weeds	
ii) Parthenocarpic fruit set	
iii) Determining sex in flower	
iv) For increasing sugar content in sugarcane	
v) Stimulation of synchronised flowering	
vi) Inhibition of bud growth	

16.6 SUMMARY

In this unit you have learnt that:

- Growth, development and differentiation are regulated by hormones.
- There are five groups of plant hormones—auxins, gibberellins, cytokinins, ethylene and abscisic acid. Except ABA which inhibits growth all hormones promote growth. Polyamines also exert regulatory control over growth and development, however, they have not been classified as plant hormones so far.
- Auxins promote cell elongation by breaking some of the bonds between the polysaccharides of the cell wall. They also promote root initiation, fruit and flower development and are involved in the development and differentiation of vascular tissues.
- The mechanism of action of plant hormones is under investigation. It is believed that most likely it is similar to that of animal hormones.
- Plant hormones have wider applications in agriculture. Auxins are used for weed control, initiation of rooting in cuttings, in tissue culture, parthenocarpic fruit set, thinning of fruit trees to obtain larger fruit size and inducing flowering. They are also used for inhibiting sprouting and bud growth. Ethylene is used for fruit ripening and synchronising flower formation. Gibberellins are used for stalk elongation of sugarcane to increase sugar content.
- Gibberellins promote growth by cell elongation and cell divisions. They restore normal growth of dwarf corn plants. During seed germination they stimulate aleurone layer to produce starch-digesting enzyme so that the embryo can get food for its development.
- Cytokinins promote cell division, remove apical dominance, delay senescence and aging, help in flower and fruit development. Together with auxin it controls shoot and root development in callus tissue.
- Ethylene is involved in fruit ripening.
- Abscisic acid is a growth inhibitor. Its levels are affected by environmental conditions. During water stress, its level increases 10 to 50 folds. It is involved in seed dormancy, stomate closure and probably in fruit, flower or leaf fall.

16.7 TERMINAL QUESTIONS

1. List the various factors that control growth and development.

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2. It is known that grain yield is unaffected if the stem length of cereal crops is reduced by dwarfing genes or by interfering with plant hormones. This is economical. Can you tell which hormone needs to be interfered with?

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3. What is the difference between animal and plant hormone?

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4. Which among the following statements is true? Write T for true and F for false in the given boxes.

   i) NAA and 2, 4-D have same effect as natural auxins produced by plants. ☐

   ii) There is controversy whether polyamines control growth and development. ☐

   iii) To initiate root formation in cuttings, it would be advisable to add little NAA in water. ☐

   iv) The present evidence indicates that the mechanism of action of plant hormones is different from that of animal hormones. ☐

16.8 ANSWERS

Self-assessment Questions

1. a) i) c, ii) a, iii) d, iv) b.

   b) i) Abscisic acid, ii) Cytokinins, iii) Auxins, cytokinins, iv) Gibberellins, v) Cytokinins, abscisic acid.

   c) i) c, ii) d, iii) a, iv) e, v) b.

   d) Auxins—shoot apex, young leaves and buds. Gibberellins—growing tips. Cytokinins—Root tips, developing seeds and in some fruits.

2. i) 2, 4-D, ii) auxins, iii) ethylene, iv) gibberellins, v) ethylene and auxins, vi) auxins.

Terminal Questions

1. These are:

   i) genetic controls,

   ii) hormonal controls and

   iii) environmental control—light, temperature, soil pH, acid rain, humidity and rain fall.

2. Gibberellic acid. Its synthesis can be blocked by the chemical 2-chloroethyl-trimethylammonium chloride (CCC).

3. Animal hormones trigger highly specific response in specific target tissues. Plant hormones work in more general, and probably in more complex way.

4. i) T, ii) F, iii) T and iv) T.