REVIEW OF LITERATURE
A number of natural phenolic compounds such as salicylic acid, \( p \)-hydroxybenzoic acid, caffeic acid and ferulic acid have been found to be active inhibitors of some growth processes. Other phenolic compounds such as the dihydrochalcone glucoside, phloridzing and its aglucone phloretin from \textit{Malus}, as well as the widely distributed ester chlorogenic acid are known to be potent inhibitors of growth (Gross, 1975). High concentrations of scopoletin reportedly inhibit, while lower concentrations stimulate, the growth of pea roots (Sirosis, 1972).

Marigo et al. (1975) have shown that exogenously supplied quinic acid causes an important increase of the phenolic content and a reduced growth of the tomato plants. The decrease in size is proportional to the stimulation of the phenolic pool and is equally obtained using other precursors of aromatic compounds like phenylalanine and cinnamic acid. Thus, polyphenol levels and growth could be related in tomato plant.

Reynold and Maravolo (1973) showed the association of phenolic compounds with development of the liverwort
Marchantia polymorpha. They were present throughout the tissue, with some localization in the basal and apical areas. Recently, Demos et al. (1975), have shown the effects of ten phenolic compounds on hypocotyl growth of mung bean. They have reported that tannic, gentisic, $p$-coumaric and vanillic acid inhibit the hypocotyl growth. Further ferulic, caffeic, $p$-hydroxybenzoic and syringic acid also showed a significant reduction in hypocotyl growth of mung bean.

Phillips (1962), examined the possibility of naringenin controlling the dormancy in other systems as well, and found that it could be used in place of coumarin to induce a light requirement for germination in lettuce varieties that are not normally light-requiring. Concentration of naringenin (40-80 mg/l) inhibits the germination of lettuce seeds and also successfully competes with gibberellic acid for dormancy control in the same system. Lavee and Erez (1969), found that prunin (naringenin 7-glucoside) which was identified in dormant peach buds, was found to act as a growth inhibitor of wheat coleoptile elongation. Two periods of reaccumulation of prunin, during October and January, fitted two periods of arrested growth of the
resting bud. They have suggested that the system glucoside-β-glucosidase might have regulatory properties in the dormant bud.

Kriventsov (1973) showed that the maximal amount of naringenin was observed during the rest period, whereas the content of chlorogenic acid at that time decreased. An increase in the amount of chlorogenic acid is seen at the active stages of bud development. The ratio of naringenin content to chlorogenic acid in buds, at a particular time, reflects more exactly the changes in intensity of the growth processes of the bud during the period of dormancy. McElim et al. (1975) found a close relationship between chlorogenic acid concentration and state of dormancy of excised twigs. Significant changes in chlorogenic and caffeic acids occurred both in tissue concentration and total amount/bud, in samples collected during winter 1973-74.

Stom et al. (1973), have shown that the products of phenols have a definite role in the inhibition of seed germination.

Ferulic acid inhibits the germination of alfalfa seed (cf. 1975- Gross). It is widely distributed in plants and was previously known as a germination inhibitor.
The existence of promoting and inhibiting flowering substances has been postulated for over 30 years. Recently it was shown by Pryce (1972), that the levels of vegetative Kalanchoe blossfeldiana contain a specific flowering inhibitory substance which was isolated and identified as gallic acid. It is also present in flowering kalanchoe plants in an active form. Charles et al. (1974), isolated and identified salicylic acid as a flower-inducing factor from Dactynotus ambrosia honey dew. Authentic salicylic acid induces flowering in Lemma gibba G3 under strict short day conditions. It is clear that salicylic acid is able to mimic the effect of long days on flowering and growth to a remarkable degree.

Sheen (1973), studied polyphenol metabolism during the growth and development of tobacco flower and capsule. He found that chlorogenic acid, scopolin and scopoletin were present in most tissues, whereas rutin and two dihydroxyphenolic glycosides concentrated primarily in the corolla and placenta respectively. Ovules contained only chlorogenic acid. As development progressed, polyphenols accounted for nearly 15% of the dry weight in the green capsule. Fertilization triggered a rapid increase of chlorogenic acid in the ovary. Thus, developmental stages
of tobacco flower and capsule were correlated with tissue contents of polyphenols.

**AS DISEASE**  The idea that the common flavonoids have a protective function in plants in relation to disease resistance is one that has long been discussed.

Phenols are highly toxic to micro-organisms. Tannins (including leucoanthocyanidins) have likewise been regarded as beneficial plant substances promoting resistance to disease in leaf, bark and heartwood.

Sherwood and Olah (1970), have shown the relation of glycosidase activity to the pathogen-induced accumulation of flavone and isoflavone (in fungal-infected alfalfa). Oliveira et al. (1972), have shown that the condensed polymeric flavanols from 5 plant sources showed antitumor activity against sarcoma 180 in mice and Walker 256 tumor in rats. Monomeric catechins were inactive; dimers were active; and there were indications that higher polymers were more active.

Fukui and Hiroshi (1973), isolated an isoflavone named leuteone from the immature fruits of *Lupinus lateus*. This
new isoflavone is having an antifungal activity. Dix (1974), identified the fungal inhibitory substance as gallic acid from the leaves of *Acer paltenuoides* L.

**EFFECTS ON**

It is believed that phenolic compounds may control the rate and patterns of growth by their effect on IAA oxidase. These compounds are supposed to be inhibitors of IAA oxidase. They interfere with the peroxidase catalyzed oxidation of IAA in *vitro* by introducing a lag, prior to the onset of IAA oxidation (Gelinas, 1973). Miller and Richard (1975), have shown that the naturally occurring coumarins such as scopoletin inhibits the peroxidase catalyzed oxidation of IAA.

Ugrekhelidze et al. (1970), have shown that catechol and hydroquinone inhibit oxidation of IAA by enzymetic extracts of pea seedling roots, while phenol and resorcinol do not prevent oxidation.

Mironyuk and Elnor (1970), have shown that the triphenols-pyrogallol, fluoroglucose and gallic acid, stimulate the absorption of oxygen; while the diphenols-hydroquinone and pyrocatechol, inhibit oxygen absorption in the cells of red alga *Dunaliella salina*. 
One ubiquitous group of phenolics, namely benzoic acids and cinnamic acids, are potent inhibitors of active potassium (Glass, 1974), and phosphate absorption (Glass, 1973), by excised barley roots. The effect is readily reversible, and the inhibitory capacity of the benzoic acids is strongly correlated with their lipid solubilities. Phenolics act directly on the cell membrane, modifying its permeability and thereby increasing the rate of efflux of ions. Thus, the inhibition of ion uptake brought about by naturally occurring phenolic acids is caused by a generalized increase in membrane permeability to inorganic ions. (Glass and Dunlop, 1974). Further, hydroxybenzoic acids also inhibit the active inorganic phosphate absorption by barley roots. Salicylate derivatives were found to be more inhibitory (Glass, 1975).

Stenlid (1963), found that all flavonoids were uncoupling agents of oxidative phosphorylation and also all affected the destruction of IAA by the pea root system. In general, all 4'-hydroxyflavonoids were co-factors for the oxidation of IAA and were thus growth inhibitors, whereas 3'-4'-dihydroxy flavonoids inhibited the destruction of IAA and were thus growth stimulators.
Demos et al. (1975), have shown the effects of phenolic substances on the respiration of isolated *Phaseolus aureus* L. hypocotyl mitochondria. Tannic, gentisic and \( \beta \)-coumaric acids inhibited respiration and prevented substrate-supported \( Ca^{2+} \) and \( PO_4 \) transport. Vanillic acid reduced mitochondrial \( Ca^{2+} \) uptake but did not affect respiration. Phenolic compounds which alter respiration or coupling responses in isolated mitochondria also inhibit hypocotyl growth.

*AS GIBBERELLIN* The widely distributed tannins appear to act as gibberellin antagonists. Chemically defined tannins were found to inhibit the gibberellin-induced growth of light-grown dwarf pea seedlings but the endogenous growth of the seedlings was not inhibited (Corcoran, 1970; Corcoran and Phinney, 1972).

Likewise, flavonoids like the flavanone naringenin which is found in dormant peach buds and the isocoumarin, hydrangenol (from *Hydrangea macrophylla* and *H. hortensia*), both antagonize the action of gibberellins (Phillips, 1962 and Asens et al. 1960).
Enzymes showing peroxidase activity are ubiquitous in plant tissues. It has been reported that peroxidase plays an active part in various metabolic processes occurring in plants. Several roles have been suggested for peroxidases, though the reasons for the presence of multiple peroxidases within a single plant has not been resolved. Indeed, the functions of peroxidases in plants are currently the subject of much discussion.

Peroxidase was observed in the cell wall, on the plasmalemma, in the Golgi apparatus, cisternae and vesicles in young and developing vacuoles, in endoplasmic reticulum (ER) and on both soluble and membrane-bound ribosomes in the onion root tip (Goff, Charlesw, 1975).

Peroxidase is detectable either in advance of cell division or accompanying cell division in proepidermis, procambium, protophloem, the primordial centres for the origin of buds and root, wound meristems and developing nucellus and embryo sac (Van Fleet, 1959),
in trichoblast and developing root hairs in certain grasses (Avers and Grimm, 1959), in scleried initials in *Rawolfia* (Mia and Pathak, 1963), and in stomatal and trichome initials (Shah, 1972).

During Palmiano and Juliano (1972), have shown an increase in peroxidase level during germination of rice seed. Further they have shown that in the dark, seed peroxidase activity increases faster and is higher than in the light.

In a study of isoenzymes of 8-day old seedlings of barley, Upadhya and Yee (1968), noted that some peroxidase isoenzymes were common to the root, coleoptile and leaf, but variations in the banding patterns of each tissue existed. Anstine et al. (1970), showed that the dry, resting barley embryo contained three major peroxidase bands; during normal germination, two of these bands slowly disappeared and several new bands appeared.

Peroxidase bands in young developing leaves of *Xanthium* were not constant in quality or quantity as growth occurred (Chen, Towill and Loewenberg, 1970). Brewbaker and Hamill (1969), have shown that maize tissues varied
greatly in isoenzyme pattern. Ontogenetic variations were observed for the leaf blade, leaf sheath and internodes during maturation and were related to the rates of tissue enlargement. The electrophoretic separation showed qualitative and semiquantitative differences between peroxidases in the cotyledon, epicotyl, hypocotyl and radical of the germinating peanut seedling (Dempsey and Nevin, 1974). Developmental studies showed that the number of bands of peroxidase increased with age of the leaf of Datura, during seedling growth, and in more mature plants (Conkling and Smith, 1971). Siegel and Galston (1967) examined peroxidases in peas and observed that each organ had a characteristic distribution pattern and that ontogenetic changes were marked in all organs examined.

Bireck and Galston (1970), observed no marked qualitative changes in isoperoxidase patterns during stem growth although the activity of particular isoenzymes changed with time. MacNicol (1973), has shown that the isoperoxidase patterns were independent of both genotype and phenotype for internode length, and polymorphism was detected involving two of the isoperoxidases.

Wise and Morrison (1971), found five isozymes in the cotton plant; one was present only in the boll and another only
in leaves; two isozymes not present in the young leaf, were present in the old leaf.

Gordon (1971), reported that peroxidase patterns differed qualitatively between leaf and internode development in the expanding leaf zone of eastern cottonwood. Verma and Hysstee (1970), have shown that quantitative and qualitative differences occur in this enzyme between groups of cells of different sizes. Nash and Davies (1975), have shown that during the growth cycle of Paul's scarlet rose cells in suspension cultures, qualitative changes in peroxidase took place.

Sheen (1973), reported 17 peroxidase isozymes during growth of tobacco flower and capsule. Among these six cathodic forms were present throughout floral development and the anodic ones increased in number and activity at the later stages of capsule growth. During the transition of vegetative to reproductive shoot apex, marked increase in the peroxidase activity was reported by Chinoy et al. (1969).

Poovaiah and Rasmussen (1973), have shown that an increase in peroxidase activity is closely tied to the development of the abscission layer in the abscission zone of bean leaves.
Henry and Valdonios (1974), have suggested that the distribution of peroxidase activity and IAA oxidase content can be correlated with the processes of natural abscission. Sheen (1973), reported that peroxidase activity was maximal during senescence of all tissues of tobacco flower and capsule.

IN RESISTANCE Stelzner (1974), has shown that the AND antimicrobial activity of a phagocyte INJURY is the result of the effects of peroxidase and lysozyme. Kandov (1974), noted an increase of polyphenol oxidase activity and decrease in peroxidase activity in wilt-infected plants of some Malvaceae species. Peroxidase activity has been localized in the cell walls and cytoplasm of wound vessel elements of coleus (Helper, 1972).

Injury-induced increases in peroxidase activity are known to occur in various organs of many plants particularly in sweet potato roots (Birecka et al. 1973). Macri (1974), noted a difference in peroxidase activity between resistant and susceptible plant and has discussed its role in resistance in corn leaves.
In studies of plant evolution and systematic similarities and differences in isozyme band patterns, has been used as evidence of the degree of phylogenetic relationships among species, e.g. in *Nicotiana* (Harf and Bhatia, 1967; Sheen 1970; Smith et al., 1970), *Phaseolus* (West and Garber, 1967), *solanum* (Desborough and Pelouin, 1967), Fabaceae (Tharman et al., 1967), *Triticum* (Johnson and Hall, 1966) and *Oryza* (Chu, 1967).

However, Juo and Stontzky (1973), have reported that the banding pattern of peroxidase isozymes from the seeds of *Pinus, Abies* an *Pseudostuga*, which ranged from 3-9 bands, also appeared to be species specific and no common trends or homologies were apparent.

MaCown (1969), found prominent changes in peroxidase isozymes in the hardy cultivars, developing additional isozymic components under winter condition. Ishida (1971), showed an increase in peroxidase activity in the shoot apex in cold treated (4-5°C) plants. Babeek and Curtis (1975), have shown that peroxidase level can be stimulated in detached leaves by an appropriate dose of germicidal UV.
Ethylene and IAA both increased the peroxidase activity in young tea shoots, but the isozymes increased by each substance were different (Saijo, Rayoyasu, 1975). Adams and Galston (1974), showed that ethylene increases the pith peroxidase activity of intact tobacco plant, but not of excised pith. Henry and Jensen (1974), have also reported ethylene-induced peroxidase activity in petiole, stem and leaf blade of cotton plants in pulvinus and separation layer of bean explant, in etiolated peas, and in sweet potato root discs.

Breck (1973), has shown that in sweet potato roots, injury-induced increase in peroxidase is attributed to the action of injury-induced ethylene, especially since exogenous ethylene has been shown to promote peroxidase activity in injured tissue. In root sections IAA had a weak inhibitory effect on one injury-induced isoperoxidase only, whereas in tobacco pith it inhibited the development of injury-induced, as well as the constitutive isoperoxidases. Galston and Leshem (1971), reported that exogenous IAA inhibited the isoperoxidases formed in excised tobacco pith tissue. Ockerse Ralph et al. (1974), have shown that in excised stem segments of Pisum sativum L. GA causes a slight reduction in activity whereas IAA completely
prevents this rise. Kinetin treatment of attached or detached axis promotes activity of essentially the same cathodic isoperoxidases. In addition, it enhances the activity of two anodic peroxidases and represses specifically that of a cathodic one (Caspar, Khan, 1973). Kinetin had profound effects on peroxidase and IAA oxidase. 0.2 μM kinetin was found to induce isoperoxidases in cytoplasmic, plasma membrane and ribosome rich fraction; a high concentration of kinetin inhibited their formation. High kinetin concentrations also lowered the specific activity of IAA oxidase and peroxidase in all subcellular fractions, but the effect was much greater on peroxidase than on IAA oxidase. Evidently, the activities of IAA oxidase and peroxidase were not equivalent and should be considered separately (Lee, 1974). Manes (1974), has shown that there was a similarity of patterns for peroxidase activity, polyphenol oxidase and IAA oxidase activities in 3 plants i.e. Solonum tuberosum, Beta vulgaris, and Ipomea batatas.

Srivastava and Van Huystee (1974), have shown that peroxidase, polyphenol oxidase and IAA oxidase were detected in peanut cotyledon cell suspension culture. On polyacrylamide gels, 5 anionic and 2 cationic peroxidase isozymes were identified. Staining of the gels for polyphenol oxidase and
IAA oxidase revealed Rf pattern for a number of isozymes that was identical with that for peroxidase. Again the elution pattern for the isozymes of the three enzymes was so similar that it can be regarded as an enzyme possessing all the three types of activity.

**BETALAINS**

The betalains represent a class of red and yellow alkaloid which have long intrigued not only natural products chemists, but plant systematists as well. The expression 'betalains' was introduced in 1966 to include both the red betacyanins and yellow betaxanthins.

As with most so-called "secondary" compounds, the question of the function, utilization and possible degradation of betalains has not been explored in detail. The betalains appear to have replaced the anthocyanins as pollination factors. However, like anthocyanins betalains probably have multiple functions, this include participation in biological oxidations producing resistance to microbial infection like the widespread, anthocyanins, betalains are water soluble, occurring naturally as salts in the cell vacuoles of flowers, fruits and leaves. Tronchet (1968) noted that both betalains and anthocyanins are often present in the epidermal layers of the plant tissue. Moreover, betalains often accumulate in the stalk, and in the red beet they are found in high concentrations in underground parts. It has also been observed that betalains
frequently accumulate at wound or injury sites in the plants that synthesize them normally (I saw, 1972).

Arnold (1964) has shown that GA$_3$ caused a marked increase in elongation in hypocotyl length in light and inhibited anthocyanin synthesis in hypocotyl segments of Impatiens balsamina, while NAA increased the anthocyanin synthesis. Ethylene has been shown to have both promotive and inhibitive effect on light induced anthocyanin synthesis (Craker, 1973). Stickland (1974) found the highest anthocyanin concentration with 4% sucrose, the highest carotenoid concentration with 0.6% sucrose. No anthocyanin was produced when the florets were grown at 6°C or 30°C, maximum yield was at 15°C.

Mancinelli et al. (1975) have found that streptomycin enhances the synthesis of anthocyanins and inhibits the synthesis of chlorophylls and the development of chloroplasts in dark-grown seedlings of cabbage, *sinapis, alba* and turnip.

Murray et al. (1975) have shown that a wide range of purine bases, nucleosides and cyclic nucleotides induced betacyanin synthesis in *Amaranthus tricolor* seedlings.
FLAVONOIDS Various classes of flavonoids are distinguished on the basis of their differing oxidation levels, suggesting that they are involved in metabolic oxidation-reduction processes of the plant. Maseulier (1951) suggests that the action of flavonoid pigment is to maintain the ascorbic acid in the reduced state at the expense of its own oxidation.

The flavonoid effect was that of making a small amount of ascorbic acid act like a larger amount. This "sparing action" toward ascorbic acid is not characteristic of all flavonoids to the same extent. A noteworthy contribution was made by Clementson and Andersen (cf, Deeds, 1968) in their study of "Plant polyphenols as antioxidants for ascorbic acid". They studied 34 flavonoids and esculetin and 6 hydroxycinnamic acids. Rutin and its aglycone quercetin had the greatest antioxidant activity. In general the flavonol glycosides and dihydroflavonols showed high antioxidant activity. In the case of in vitro studies the low solubility of many flavonoids, especially their aglycones has resulted in a variety of methods to dissolve them and this may have contributed to contradictory results.
A comparison of the flavonoids in this respect and an understanding of the mechanism of action required a quantitative investigation of the ascorbic acid - flavonoid relationship, and a correlation of the results with other known properties of flavonoids.