herbarium and a research laboratory specially equipped for work on marine and freshwater algae as well as rooms for staff and postgraduate research workers. Further accommodation for staff and postgraduate students is provided on the first floor, which also houses a small lecture room (seating seventy), the library and separate reading room.

On the top floor, which is wholly allotted to botany, there are two large teaching laboratories for general botany, providing places for sixty-two and forty-eight students, respectively. Since these laboratories are placed back to back and divided only by swing doors, they can when occasion demands be treated as a single unit. In these and in the small honours work laboratory (capacity sixteen students) there is ample space for demonstrations and (as in the forestry laboratory) each student is provided with an adjustable 'Anglepoise' lamp and a microscope lamp made to the Department's specification. Only a limited amount of overhead lighting is provided. The small laboratory for advanced mycology is similarly designed.

Also on the top floor are the laboratories for plant physiology. The teaching laboratory, holding sixty students, resembles a well-equipped chemical laboratory. The benches are provided with electrically heated water baths, but not gas, and there are vacuum and compressed air points. There is overhead fluorescent lighting and an adjacent balance room. Near by is a small research laboratory and preparation room.

The semi-basement, in addition to housing the Forestry Department's wood-working shop and instruments store previously mentioned, provides the Botany Department with two photographic dark-rooms, a general photographic room, a workshop and sorting room and two constant-temperature rooms.

In his introductory speech at the opening ceremony, Lord Kenyon, president of the College, said that the completion of the new science buildings was an event second in importance only to the opening of the College itself. He expressed the thanks of the College to the University Grants Committee for the financial support which had made the post-war building programme possible.

Sir Keith Murray then spoke of the significance of the occasion as marking the increasing importance of science, and especially of biology, to-day. That the College had found it necessary to increase the accommodation for all its science departments and not only for some of them illustrated the breakdown of the lines of demarcation between the different sciences and the need for training in the fundamental sciences as the basis of all scientific education.

After emphasizing the growing importance of the biological sciences because of the rise in world population and the consequent pressure on food supply and other natural resources, Sir Keith went on to say that the duty of a university is to turn out men and women with minds which are trained and not merely stored with facts; this training should be carried out not merely by formal instruction in the lecture room and laboratory, but by informal contacts between the students and the more mature minds of their teachers, as well as by the contacts of student with student in daily work and extra-curricular activities. The latter are as valuable a part of a university education as the work covered by the examination syllabus.

Sir Keith Murray was thanked by Sir Emrys Evans, principal of the College, and finally the College's gratitude to the architect and the contractors was expressed by Sir Wynn Wheldon and Lady Artemus-Jones, vice-presidents.

PLANT GROWTH SUBSTANCES

THIRD INTERNATIONAL CONFERENCE

THE Third International Conference on Plant Growth Substances was held at Wye College (University of London) during July 17-22. The organizer was Prof. R. L. Wain, head of the Department of Chemistry in the College and director of the Agricultural Research Council Unit for Plant Growth Substances and Systemic Fungicides. D. F. Wightman acted as conference secretary.

The emphasis of the papers and discussions was on the biochemical aspects of the subject but not confined, as in the preceding conference at Lund in 1953, to considerations of the relationships between chemical structure and biological activity. Although two whole sessions were devoted to this topic, the remaining four on the natural auxins, auxin metabolism and mechanism of action promoted the more vigorous discussions.

The two years that have elapsed since the Lund Conference have seen the almost universal adoption of paper partition chromatography as a tool in the study of naturally occurring plant growth substances. The opening session of the Conference clearly demonstrated how valuable this new tool has been in tackling the involved problems of the nature of the natural auxins. Dr. J. P. Nitsch (Harvard

University), in a systematic study of extraction, separation and assay methods, has revealed the dangers of using ether as a solvent for extractions in the cold since enzyme activity may still persist in this solvent. Absolute methanol or ethanol are much to be preferred. He also demonstrated how different solvents could change the pattern of active substances extracted, thus illustrating the dangers of too narrow an application of stereotyped techniques. Another, until recently unsuspected, danger was the use of ammonia as a component of the chromatographic solvent for the separation of acid growth substances. Considerable hydrolysis of certain substances may occur during the running of the chromatogram. This presumably accounts for the interconversions of neutral auxin precursors extracted from a variety of plant tissues by Dr. J. A. Bentley and Mr. S. Housley (University of Manchester). Dr. Nitsch also introduced a new assay technique, using segments from the first internode of oat seedlings. This he claims has a sensitivity greater than that of the oat coleoptile curvature test and can measure quantities of indole-3-acetic acid of the order of 0.001 μgm . This makes it possible to study small quantities of tissue such as apical meristems, 200

mgm. of which is sufficient to allow an accurate assay. In a number of papers and in the discussions which followed, the reliability of the usual colorimetric tests for indole compounds came under review. Both Dr. Nitsch and Dr. A. J. Vlitos (New York) have perfected reliable quantitative methods for measuring colour intensity of spots on paper chromatograms, allowing accurate estimations of indole compounds when present in relatively high concentrations.

Chromatographic techniques in the hands of Prof. Hans Söding and Dr. Edith Raadts (Hamburg) have been turned to the solution of the old enigma of the nature of auxin in the oat coleoptile. Indole-3-acetic acid was found in quantity in the diffusates from apex and base of that organ together with an unidentified growth-promoting substance. Two growth inhibitors and a precursor of indole-3-acetic acid were also isolated. Similar techniques have been employed at Wye College to study changes in growth substance content of the various organs of germinating seedlings (Miss P. M. Cartwright, Mr. J. T. Sykes and Prof. R. L. Wain). The results point to the conclusion that indole-3-acetic acid has no part to play in the germination processes themselves but is important in the growth of the young shoot. One interesting point was the detection of indole-3-carboxylic acid in these seedling extracts, a compound which might be derived from indole-3-acetonitrile by α -oxidation, as shown in the contribution of Mr. R. C. Seeley and his collaborators (Wye College).

Exciting discoveries of new growth substances from the endosperms of seeds were announced by Prof. F. C. Steward (Cornell University). Using a new technique of plant tissue culture, permitting the study of free-floating cells, the separate effects of natural growth substances on cell division, cell expansion and cell differentiation could be followed. Four nitrogenous substances, highly active in stimulating cell divisions, have been isolated from coconut milk by heavy-metal precipitations. One of these substances has been identified unequivocally as 1-3-diphenyl-urea. Its action has been confirmed on carrot, artichoke and potato tissue. Nitrogen-free substances with a similar action have been extracted from immature *Aesculus* fruits and from coconut milk. These substances belong to the general class of leucoanthocyanins, although their final identity is not yet known. It seems, therefore, that the power of stimulating the cell to divide is not the sole prerogative of any single molecule.

The sessions on the relationships between chemical structure and biological activity in the auxins received the greatest share of the formal papers. Prof. H. Veldstra (University of Leyden), in a review of recent advances, directed attention to a range of new substituted benzoic acids the structure-activity relationships of which point strongly to a physico-chemical action of the molecule acting via its stereochemical relationships rather than to a purely chemical combination with a receptor at specific reactive points in the molecule. This was to some extent emphasized by the results of Dr. L. C. Luckwill and D. Woodcock (Long Ashton, Bristol), who pointed out that the effects of chlorine substitution in the 2-naphthoxyacetic acids would, on a chemical combination hypothesis, require the unlikely postulate of a specific combination of receptor with five separate points in the auxin molecule. Prof. Veldstra pointed to another interesting development, namely, the discovery that the carboxymethyl-N:N-dialkyl-

dithiocarbamates are active as auxins. This is the first case of an active compound not possessing an unsaturated ring and adds considerable support to Veldstra's physico-chemical hypothesis of auxin activity. Previous work had strongly suggested that in the optically active propionic acid series of synthetic auxins (+) forms were almost always active, whereas the corresponding (−) forms were inactive or auxin antagonists. The work of Dr. J. M. F. Leaper (Ambler, Pennsylvania) and Dr. B. Åberg (University of Uppsala) with the naphthalene derivatives showed this to be an over-simplification, since both forms can be auxins, their relative activities depending on the test plant employed. Prof. R. L. Wain and colleagues (Wye College) described extensive experiments in the structure-activity relationships of homologous series of ω -(2,4-dichlorophenoxy)-alkane carboxylic acids, amides and nitriles. It was shown that the alternation of activity with increasing side-chain length in both acids and amides could be correlated with the appearance of 2,4-dichlorophenoxyacetic acid in the tissue, presumably produced by the β -oxidation of the side-chain. With the nitriles, all homologues showed activity, suggesting the hydrolysis of both $-\text{CN}$ and $-\text{CH}_2\text{CN}$ groups to $-\text{COOH}$. A similar alternation of activity in the tomato ovary test was shown by Dr. L. C. Luckwill and D. Woodcock (Long Ashton, Bristol) for the 2-naphthyloxy-series of acids, but here β -oxidation was blocked completely by chlorine substitution in the 3 position in the ring, only the acetic acid being active.

The controversial questions concerning the structure-activity relationships of 'anti-auxins' in root growth were discussed by Dr. B. Åberg (University of Uppsala) and Prof. Hans Burström (University of Lund). Dr. Åberg demonstrated that much of the conflicting evidence from previous work may have been due to the use of different test materials, since wheat roots are much more sensitive and more easily stimulated by anti-auxins than flax roots. In the phenoxy-*iso*-butyric acids and some other similar anti-auxins which stimulate root growth, para-substitution in the ring was shown greatly to increase activity. The dangers of using gross elongation of roots as a measure of activity in these compounds was pointed out by Prof. Burström from a study of the interactions of β -naphthoxyacetic acid (inhibiting auxin), three of its chloro-substituted derivatives, indole-3-acetic acid and α -(3-indole)-*iso*-butyric acid (anti-auxin). There seems to be two phases in root cell elongation on which different compounds may have different actions, may also show different mutual interaction patterns or may not interact at all. The great importance, therefore, of paying due attention to the heterogeneity of the cell elongation mechanism in structure-activity studies was heavily stressed. Out of these considerations active discussion turned on the role of indole-3-acetic acid in normal root growth. No measure of agreement was reached.

Much attention was paid to theoretical considerations underlying structure-activity relationships. Dr. J. van Overbeek (Modesto, California), in a consideration of the properties of a group of suspected auxin antagonists, the maleimides, and a new class of plant growth inhibitors, the phosphonoxides, showed that a close relationship exists between activity and lipid solubility and suggested, therefore, that ease of penetration through protoplasmic membranes might explain structure-activity relationships. Drs. H. Linser and K. Kaindl (Linz) discussed

the relationships of molecular shape and size to stimulatory and inhibitory activity in oat coleoptile growth. An extensive mathematical treatment of the curves relating applied concentration to growth response to single substances and mixtures, based on the concept of molecules competing for various receptor 'holes' at growth centres in the cell, was subjected to some criticism by the physiologists. It was felt that such a simple concept ignored both the fundamental differences in action which must exist between auxins and toxic inhibitors such as eosin and also the possibility of metabolic interactions. This view was supported by the finding of Prof. L. J. Audus and Miss R. Thresh (Bedford College, London) that the auxin antagonist 2,3,5-tri-iodobenzoic acid may exert its physiological actions by lowering dramatically the level of endogenous indole-3-acetic acid in plant tissues. The application of the methods of enzyme kinetics to the study of auxin-anti-auxin interactions, as developed by Prof. J. Bonner (California Institute of Technology), came under full discussion. It was agreed that the technique had its uses, provided it was applied with the greatest circumspection.

Some four or so papers were concerned with the metabolism of indole-3-acetic acid and related compounds in the plant. In a critical review of the biogenesis of this compound, Dr. S. A. Gordon (Lemont) considered new data bearing on the pathways of its production from tryptophan. The current view is that it may be degraded to indole-3-acetaldehyde via either tryptamine or indole-3-pyruvic acid and thence via the aldehyde to indole-3-acetic acid. Alternatively the pathway suggested is a branching at the iminopropionic acid to yield the acetonitrile, which is then hydrolysed to indole-3-acetic acid via the acetamide. However, various considerations were discussed which indicate that the above specific pathways, though potentially operative in plants, do not normally function in indole-3-acetic acid formation. The hypothesis was presented that tryptophan goes to indole-3-acetic acid via a sequence analogous to the pyruvate dehydrogenase mechanism, that is, indole-3-pyruvic acid to indole-3-acetic acid through the acyl lipolate directly or through the coenzyme A ester. The differing abilities of various plant species to hydrolyse indole-3-acetamide and indole-3-acetonitrile to indole-3-acetic acid were clearly demonstrated by Mr. R. C. Seely and collaborators at Wye College. Thus the amide is extensively converted to the acid by pea, tomato and maize tissue but not by wheat and celery, whereas the nitrile is converted by wheat and maize but not by the other tissues. The fate of indole-3-acetic acid fed in high concentrations to tissues was discussed by Dr. A. W. Galston (California Institute of Technology), who showed that a fraction may be actively bound to cytoplasmic proteins. The greater portion, however, is oxidized by the action of a peroxidase system induced by the high indole-3-acetic acid concentrations applied. Both the peroxidase and the peroxide-producing moieties of the total system are so induced. It was suggested that this phenomenon accounts for the normal cessation of cell elongation and the subsequent onset of lignification by the oxidation of lignin precursors of the eugenol type by this induced peroxidase system.

Little attention was given to the role of indole-3-acetic acid in physiological processes in plants. Prof. P. Larsen (University of Bergen) presented data on

geotropic responses of roots pointing to the validity of the classical Went-Cholodny theory. The role of auxin in the flowering of short-day plants was discussed by Dr. A. J. Vlitos (Boyce Thompson Institute, New York). Contrary to current theories, indole-3-acetic acid levels in short-day photoinduced plants of Biloxi soy bean and Maryland Mammoth tobacco are much higher than in non-induced plants.

The final session of the conference was devoted to papers and discussion on the mechanism of auxin action. Prof. J. Bonner (California Institute of Technology), in an extensive investigation into the osmotic relations of growing oat coleoptile segments, returned to the conclusions put forward a quarter of a century earlier by Heyn, that the ultimate action of auxin must be in the cell wall. In an elegant series of experiments in which segments were treated with indole-3-acetic acid and then prevented from growing by osmotic means, he demonstrated a persistent effect on wall properties independent of any effect arising as a result of growth. Water permeability was dismissed as a possible factor, from studies with deuterium-labelled water. The results of extensive studies on auxins and absorptive processes were presented by Prof. G. E. Blackman (University of Oxford). The actions of 2,4-dichlorophenoxyacetic acid on growth and absorption of nitrogen, phosphorus and potassium are not obviously related. *Lemna minor* and *Salvinia natans* differ considerably in their responses. Radioactively labelled 2,4-dichlorophenoxyacetic acid is rapidly taken up by these plants, but after four hours a loss from the tissues is observed. The temperature sensitivity of this loss suggests that it is not an exchange action but an active export of the auxin molecule. Pre-treatment of plants with very dilute solutions of the acid considerably reduces subsequent uptake, giving a possible explanation of the reduced sensitivity of such pre-treated plants to toxic levels of 2,4-dichlorophenoxyacetic acid treatment. The role of coenzyme A in growth processes mediated by auxin was discussed by Dr. A. C. Leopold (Purdue University, United States). Most striking was the effectiveness of supposed anti-auxins, for example, 2,3,5-tri-iodobenzoic acid, 2,4-dichloroanisole and coumarin, in blocking the effective —SH groups in the coenzyme. The inadequacies of a previous theory of growth substances action based on coenzyme A esterification were discussed in the light of new findings. Prof. T. A. Bennet-Clark (King's College, London) presented a new theory to explain auxin action on cell wall extensibility. Evidence was presented that this extensibility might be closely bound up with the state of pectic substances in the growing cell wall and the nature and intensity of the cross-linking forces between the molecules. Further evidence suggested that methylation of these pectic substances and also their relationships with calcium ions might play a part in wall changes and that choline and choline-esterase might be involved. The marked inhibiting action of indole-3-acetic acid on choline esterase activity adds support to these views. Other views on possible mechanisms were expressed during the conference. Prof. H. Veldstra directed particular attention to nucleic acid metabolism, an aspect so far neglected in auxin studies. Prof. F. C. Steward made a similar plea for nitrogen metabolism.

The papers given at the conference are to be published in a special volume which, it is hoped, will appear well before the end of the year.

L. J. AUDUS