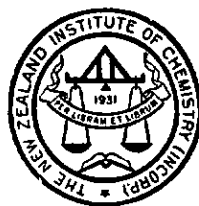
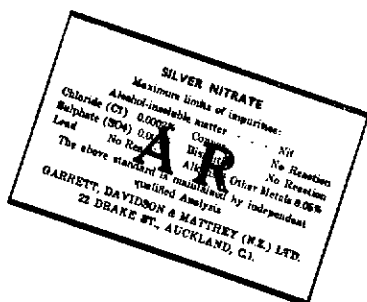
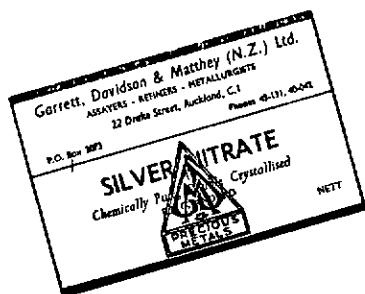


JOURNAL OF THE NEW ZEALAND  
INSTITUTE OF CHEMISTRY

Vol. 26 No. 3  
June, 1962





# CHEMICALS

by

**Garrett, Davidson & Matthey (N.Z.) Ltd.**

*The following chemically pure and Analytical Reagent quality  
"CHEMICALS" are manufactured in our laboratory to  
the highest "world standards"—*

SILVER NITRATE C/P.

SILVER NITRATE A/R.

SILVER NITRATE  
DENTAL

SILVER CYANIDE  
SINGLE SALT

SILVER SALT  
(ready mix)

SILVER IODIDE

SILVER IODATE

SILVER OXIDE

GOLD METAL C/P.

GOLD CHLORIDE

GOLD PLATING

SOLUTION

GOLD PLATING SALTS

PLATINUM BLACK

PLATINIZED

ASBESTOS

PLATINUM CHLORIDE

RHODIUM SOLUTION

ELECTROLYTIC

CLEANING SALTS

"QUALTEST" OUTFIT

(Testing precious metals)

AMMONIA C/P.

\*

22 Drake Street      AUCKLAND      P.O. Box 2073

Telephone: 21-786 (2 Lines)      Telegraphic Address: "Rollers"

# JOURNAL OF THE NEW ZEALAND INSTITUTE OF CHEMISTRY

Vol. 26, No. 3

June, 1962

## CONTENTS

	<i>Page</i>
Local Membership .....	65
Conference, 1962 .....	67
Branch News and Notes .....	69
The Registry .....	69
The Chemical Control of Plant Growth ..... <i>R. H. M. Langer</i>	71
New Functions for Vitamins ..... <i>M. H. Briggs</i>	84
Chemistry and Food Technology ..... <i>J. K. Scott</i>	94
Book Reviews .....	104
Books Received .....	109

---

*Published for the New Zealand Institute of Chemistry  
(Inc.), P.O. Box 250, Wellington, by*

**EDITORIAL SERVICES LIMITED**  
20 Binham Street. Telephone 51-416.  
C.P.O. Box 2721. Wellington, N.Z.

*United Kingdom Advertising Representative  
Walter Judd Ltd., 47 Gresham Street, London, E.C.2.*

---

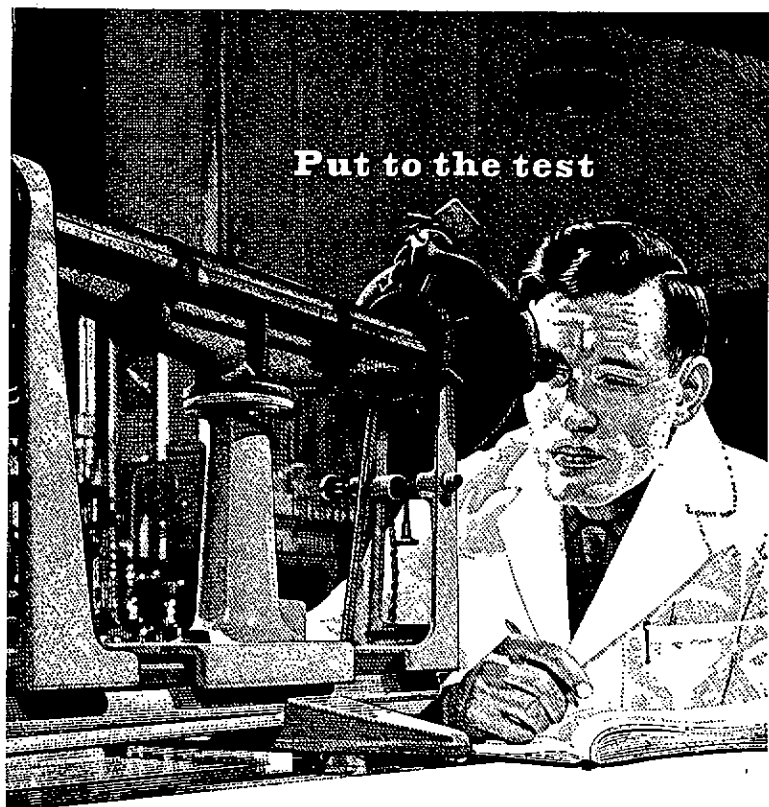
*Edited by N. T. CLARE*  
109 Cambridge Road, Hamilton, N.Z.

---

*Registrar, N.Z. Institute of Chemistry (Inc.)  
D. J. Hogan, P.O. Box 1926, Christchurch, N.Z.*

*Employment Officer*  
E. G. Borthwick, Shell Oil N.Z. Ltd.,  
Box 2091, Wellington.





**Put to the test**

Samples from every batch of M&B laboratory chemicals are subjected to stringent tests by May & Baker analysts - you can be sure that each M&B chemical you use conforms to our high standards of specification.

Our extensive range of M&B laboratory chemicals has been developed to meet all everyday analytical and educational needs as well as to provide a selection of chemicals for specialized laboratory work.

*Detailed information is available on request*

**M&B** LABORATORY CHEMICALS *and* REAGENTS  
*brand*

# WHAT'S NEW FROM B.D.H. ?



## GLASS BEADS for chromatography

The beads have an average diameter of 0.177 mm (A.S.T.M. Grade 80). They are an excellent packing for gas/liquid chromatographic columns, requiring less liquid, and giving shorter retention times and sharper peaks, without loss of resolution, than most supporting materials<sup>1</sup>. Dinonyl phthalate, glycerol<sup>2</sup> and silicone oil<sup>3</sup> are among the liquids which have proved highly successful in combination with glass beads, and several impressive separations have been reported.

- 1) *Chem. Eng. News*, 1960, 38 (16), 115.
- 2) Callear, A. B. and Cvetanovic, R. J., *Canad. J. Chem.*, 1955, 33, 1256-67.
- 3) Hishta, C., et al., *Anal. Chem.*, 1960, 32 (7), 880.

## 4-(2-PYRIDYL-AZO)- RESORCINOL DISODIUM SALT (PAR)

**A colorimetric reagent for cobalt and other metals**

PAR has been claimed to be the most sensitive of all reagents for the colorimetric estimation of cobalt, the most sensitive water-soluble reagent for uranium, and perhaps the only water-soluble reagent for the colorimetric determination of lead<sup>1</sup>. In addition, it is a versatile complexometric indicator in direct titrations of metal ions with EDTA<sup>2</sup>, and of indium with nitrilo-triacetic acid<sup>3</sup>.

- 1) Pollard, F. H., Hanson, P., and Geary, W. J., *Anal. Chim. Acta*, 1959, 20, 26-31.
- 2) Wehber, P., *Z. anal. Chem.*, 1959, 166, 186-9.
- 3) Busev, A. I., and Kanaev, N. A., *C.A.*, 1959, 53, 18747c.

## 'pH VALUES and their DETERMINATION'

**A new edition**

During the last thirty years many thousands of copies of this B.D.H. booklet on pH values have been distributed in the United Kingdom and abroad. The seventh edition entitled "pH Values and their Determination" is now available. It has been completely re-written in relation to current theory and practice, and includes a discussion of electrometric methods. Copies are free.

## 'PHOSPHATE ESTERS IN METABOLISM': A new publication

An up to date account of some of the most important phosphate esters is given in this new B.D.H. booklet, including the hexose, pentose and triose phosphates and ATP, DPN, TPN, uridine diphosphoglucose, phospho-*enol*-pyruvic acid and phytic acid. References are given to methods of preparation and analysis, and a useful feature is a metabolic chart showing the inter-conversions of hexose and hexose phosphates. A large amount of information has been gathered together from various sources and the booklet should be of use to workers in many fields. Copies are free and will gladly be sent on request.

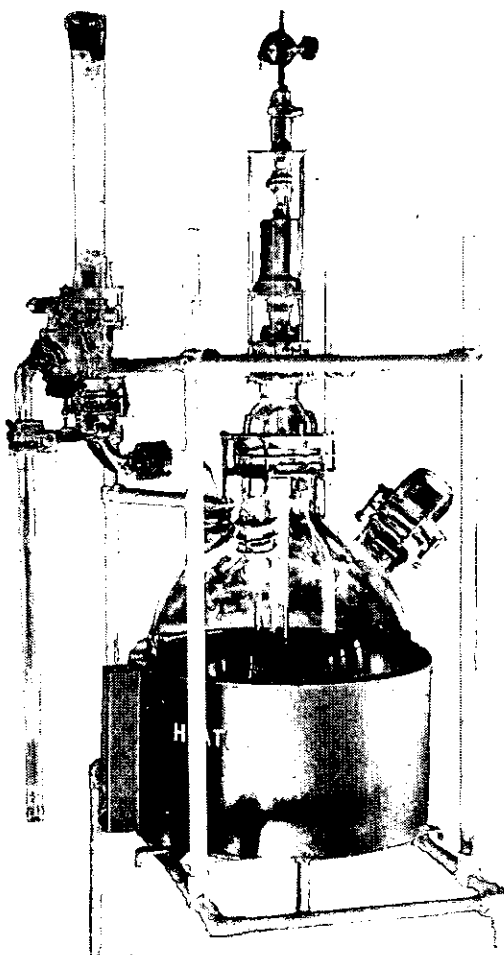
THE BRITISH DRUG HOUSES LTD.

B.D.H. LABORATORY CHEMICALS DIVISION · FOOLE · ENGLAND



## GLASS PLANT & PIPE LINE

Q.V.F. Industrial Plant is now in use in almost every country in the world and is proving its efficiency in an ever increasing range of industries. There is now available a range of Q.V.F. Pipe Line from  $\frac{3}{8}$  in. (15mm.) to 18 in. (450mm.) diameter, also fractionating columns and absorption towers in diameters up to 18 in. and Heat Exchangers in individual units up to a surface area of 60 sq. ft. (5.6 sq. metres).



If your particular problem is—  
**ATMOSPHERIC POLLUTION  
 ABSORPTION  
 BY-PRODUCT RECOVERY  
 BATCH REACTION  
 CORROSION  
 DRYING  
 GAS GENERATION or  
 PURE ACID PRODUCTION**

there is a range of standard Q.V.F. glass plant—as complete "Packaged Units"—available to meet your special requirements and ready for erection in your works.

Also Available:

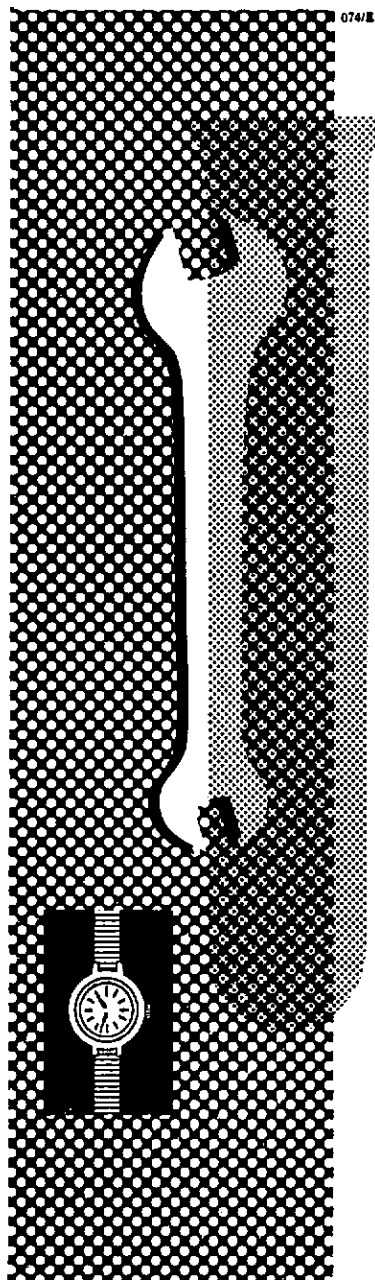
- GLASS PUMPS
- GLASS VALVES
- VIBROMIXERS
- ELECTRO MIXERS
- REFLUX RATIO TIMERS

# J. & A. G. MURRAY LTD.

P.O. BOX 1716

'PHONE 48-318

AUCKLAND



### Always make the right choice!

The heavy wrench might be suitable for repairing a tractor. No doubt that it is not the appropriate device to treat the delicate wrist-watch with.

Corresponding parallels are to be found also in chemistry, for example, in analysis the specially tested "Guaranteed Reagents Merck" are „appropriate devices“.

We supply numerous chemicals in various degrees of purity:

- purified
- pure
- extra pure
- **Guaranteed Reagent**

For every scope the specific preparation is available with us and the selection only proves the expert.

Let us help solving your problem!

E. MERCK AG



DARMSTADT

Germany

Sole Agents in New Zealand:  
Henry H. York & Co. Pty. Ltd.,  
P. O. B. 6434, Wellington

Supplies of Laboratory Chemicals through:  
Watson Victor Ltd., Auckland,  
Wellington, Christchurch, Dunedin

# JOURNAL OF THE NEW ZEALAND INSTITUTE OF CHEMISTRY

Vol. 26, No. 3

June, 1962

## LOCAL MEMBERSHIP

Much consideration is being given by the Institute Council and branch committees to the two grades of membership of the Institute. It appears that the proportion of Fellows to Associates is much lower in the New Zealand Institute of Chemistry than in corresponding bodies in other Commonwealth countries, mainly because many senior Associates well qualified for the Fellowship have not applied for it. Provisions to induce these members to seek Fellowship status will no doubt be included in the revision of the Rules now in progress.

There is another form of membership which can easily be overlooked, because it is strictly not a membership of the New Zealand body but only of a branch. This is the Local Membership. Local members are persons interested in chemistry, and generally engaged in the practice of it, who do not possess the qualifications necessary for Associateship. They form a heterogeneous group, for a local member may be a very junior laboratory technician or a highly experienced analyst with a sheaf of publications to his credit. A case can be made in fact for creating a third, limited, degree of membership of the Dominion body to include the more qualified and experienced local members under the surveillance of the Membership Committee. At present local members are enrolled solely at the discretion of the branch committees. They have the right to attend branch meetings and the Annual Conference and to receive the *Journal*, but not to vote on branch or Institute affairs.

Their subscription fee is that set by the branch for all its members, plus the cost of the *Journal*. Because a substantial part of the branch organization expenses are met by a grant from the Council out of the fees contributed by Fellows and Associates, the local member receives virtually all the benefits of the whole organization except a voice in its government and the professional qualification for rather less than cost price. Let not this statement be construed as a complaint, for local membership is a valuable institution and many in its ranks have played a worthy part in the work of their branches; yet it is desirable that the facts should be known.

Membership of any organization carries not only privileges but also responsibilities. In professional ethics our local members appear to have upheld the standards of their more qualified colleagues. (We know of only one example of a local member attempting to trade on his association with the Institute—his addition of the letters L.M.N.Z.I.C. after his name was rather damaging to his case when the Director showed his application to the Chief Chemist of the firm). We have, however, heard complaints from Institute officers that branch secretaries appear to lose track of their local members very easily, with the result that the *Journal* is sent to the wrong address or to persons who have ceased to pay subscriptions; and from branch secretaries that local members are lax in notifying them of changes and resignations.

Perhaps part of this problem lies in the more nomadic nature of the local member. He is a welcome unit of the Institute and may his tribe increase; but may he not forget the obligation to inform the branch secretary when he pitches his tent in a new place. And may Fellows and Associates reading this admonition remember that they too are not always free from this same fault.

---

### **Dr F. J. Llewellyn—Chairman, New Zealand Broadcasting Corporation**

Dr F. J. Llewellyn, Chairman of the University Grants Committee, recently undertook a further, and, for a Fellow of the Institute, unusual responsibility when he was appointed Chairman of the newly-constituted New Zealand Broadcasting Corporation. Dr Llewellyn was formerly Professor of Chemistry at Auckland and then Vice-Chancellor and Rector of the University of Canterbury before assuming chairmanship of the Grants Committee last year. Dr Llewellyn's positions provide silent comment on the implication, in recent Press controversy on a Public Service appointment, that a training in science was inimical to a career in administration.

## CONFERENCE 1962

The 1962 Conference of the N.Z.I.C. will be held at Lincoln College of the University of Canterbury from Wednesday, August 15 to Friday, August 17.

## PROGRAMME

There has been a good response to the request for papers. A complete programme giving the titles and abstracts of papers to be read will appear in the August issue of the *Journal*. The following tentative programme has been drawn up:

*Wednesday Morning:* Registration, Opening, A.G.M. of N.Z.I.C., A.G.M. of New Zealand Section of R.I.C.

*Afternoon:* Papers.

*Evening:* Public lecture in conjunction with the Science Congress.

*Thursday Morning:* Papers.

*Afternoon:* Presidential Address in Christchurch, visit to Exhibition and possible excursions.

*Evening:* Social function.

*Friday:* Papers.

## SCIENCE CONGRESS

The tenth New Zealand Science Congress will be held in Christchurch from August 13 to August 17. The registration of members and official opening will be on the Monday morning. The present intention is to have the chemistry section on Monday afternoon and Tuesday morning.

A special fee of 10s. has been arranged for N.Z.I.C. Conference members who also wish to enrol for Congress. It should be sent to the Conference Secretary with your enrolment form and he will forward it to Congress.

## ACCOMMODATION

Charges at Lincoln College Hostel are 27s. 6d. a day, with a *maximum* charge of £6 a week. Accommodation will be in single, centrally-heated rooms. The College provides bed linen, a towel and two blankets. Arrangements have been made to allow members to take up residence from the morning of Sunday, August 12 onwards.

## EXHIBITION

A trade exhibition is being arranged in Christchurch from August 14 to August 16 in collaboration with the Science Congress. Members will be able to visit it on either Tuesday or Thursday afternoon.

## CONFERENCE FEE

This will be 30s. for members of the N.Z.I.C. or R.I.C. and £3 for non-members except that for bona-fide students the fee will be 15s. In addition, there is a Lincoln College Students' Association fee of 5s. for residents and 2s. 6d. for non-residents.

## A.N.Z.A.A.S. CONGRESS—SYDNEY, AUGUST, 1962

## SECTION B : CHEMISTRY

The Jubilee Congress of A.N.Z.A.A.S. will be held in Sydney from August 20 to 24, 1962. The President of Section B will be Professor J. Packer, University of Canterbury, and the Vice-Presidents will be Professor R. J. W. Le Fevre, Sydney University, and Professor D. P. Mellor, University of New South Wales.

Professor Packer will deliver the Presidential Address on "Reactivity and Molecular Structure of Organic Compounds". Each subject for discussion will be introduced with a review by the speaker shown below.

- (1) The Impact of Instrumentation on the Development of Chemistry (Professor R. C. L. Bosworth, University of New South Wales)
- (2) The Chemistry of the Utilisation of Mineral Resources (Mr I. E. Newham, Chief of the Division of Mineral Chemistry, C.S.I.R.O.)
- (3) Organometallic Compounds [Interpreted to include all metal-organic compounds except co-ordination compounds]  
(Dr J. M. Swan, Division of Organic Chemistry, C.S.I.R.O.)
- (4) Surface Chemistry: Mobile and Solid Surfaces, with Applications to Such Fields as Emulsion Polymerisation and Biology  
(Professor A. E. Alexander, University of Sydney)
- (5) Recent Developments in Analytical Chemistry  
(Dr A. Bryson, University of New South Wales)
- (6) Biological Macromolecules  
(Professor D. O. Jordan, University of Adelaide)
- (7) Recent Developments in the Application of Radioactivity to Chemistry  
(Dr J. F. Duncan, University of Melbourne)
- (8) Hetero-aromatic Chemistry  
(Professor G. M. Badger, University of Adelaide)

The Programme Secretary for Section B is Associate Professor R. W. Green, School of Chemistry, Sydney University.

Other A.N.Z.A.A.S. features of interest to chemists will be:

The Liversidge Lecture, to be delivered by Dr A. R. H. Cole, University of Western Australia, on "Infra-red spectroscopy and molecular structure".

A pre-A.N.Z.A.A.S. conference on "Co-ordination Chemistry", August 15 to 17 at Sydney University. Information can be obtained from Miss B. Stevenson, Secretary, Australian Chemical Meetings Organising Committee, School of Chemistry, Sydney University.

An extensive exhibition of the "Tools of Science".

## BRANCH NEWS AND NOTES

### AUCKLAND BRANCH

The Degree of Doctor of Philosophy of the University of New Zealand was conferred on Mr P. S. Rutledge and Mr J. L. Hoare at Auckland on May 4.

Dr J. Packer, formerly of the Institute of Nuclear Sciences, has taken up his appointment as Lecturer in the Chemistry Department, University of Auckland.

### WELLINGTON BRANCH

Mr L. F. Addis-Smith, Managing Director of H. W. Lawrence and Sons Ltd., of Johnsonville, has recently visited Canada and the U.S.A., where he read research papers to the Annual Meeting of the Association of Official Racing Chemists at Los Angeles.

Mr W. J. McCabe, of the Institute of Nuclear Sciences, has left for a period with the Atomic Energy Research Establishment at Harwell. He will be in England for two years.

Dr P. P. Williams, Dominion Laboratory, Wellington, together with his wife Mrs Mary Williams, have recently returned from England, where Dr Williams held a National Research Fellowship at Cambridge University.

---

## THE REGISTRY

### Fellows

(Elected May 11, 1962)

CAMPBELL, Arthur Derek, M.Sc., Ph.D., A.R.I.C., Chemistry Department, Otago University (Senior Lecturer).

HUBBARD, Edmund Francis, Hutt Railway Workshops, Woburn, Lower Hutt (Chief Chemist).

POLLARD, John Scott, B.Sc., Dip.Ind.Chem., A.M.I.Chem.E., British Pavements. Ltd., Christchurch (Chemical Engineer).

WALKER, Ian Kenneth, M.Sc., D.Sc., Dominion Laboratory, Lower Hutt (Director).

WILKINSON, Leslie, M.Sc., Dominion Laboratory, Christchurch (Principal Scientific Officer).

### Associates

(Elected May 11, 1962)

BLIGHT, Margaret Mary, M.Sc., Dominion Laboratory, Lower Hutt (Scientific Officer).

CREAMER, Lawrence Kenneth, M.Sc., Chemistry Department, University of Canterbury (Ph.D. Research Fellow).

CHESEMAN, Trevor Percival, M.Sc., Chemistry Department, University of Auckland (Teaching Fellow).

ENTWISTLE, Evelyn Ruth, B.Sc.(Hons.), Ph.D. (St. Andrews), School of Home Science, Dunedin (Lecturer in Textiles).

- GALLOWAY, Warren John, M.Sc., Chemistry Department, University of Canterbury (Ph.D. Research Fellow).
- GRANT, Peter Kemnitz, M.Sc.(Hons.), (Lecturer) Chemistry Department, University of Otago, Dunedin.
- HAPPER, Duncan Alan Robert, B.Sc.(Hons.), Chemistry Department, University of Canterbury (Ph.D. Research Fellow).
- KERR, Ivan James, M.Sc., Buckley & Young Ltd., Wellington (Technical Sales Representative).
- KIRK, David Neville, B.Sc.(Hons.), Ph.D.(Lond.), Chemistry Department, University of Canterbury (Lecturer).
- MAHON, William Antony John, M.Sc.(Hons.), Dominion Laboratory (Scientific Officer).
- MOORE, William Alexander, B.Sc., BALM Paints Ltd., Auckland (Technical Officer, Works Laboratory).
- PHILLIPS, Leon Francis, M.Sc., Ph.D.(Cantab.), Chemistry Department, University of Canterbury (Lecturer).
- QUICKENDEN, Terence Ivan, M.Sc., Chemistry Department, University of Canterbury (Ph.D. Student).
- ROBINSON, Ward Thomas, M.Sc., Chemistry Department, University of Canterbury (Ph.D. Student).
- ROPER, Warren Richard, M.Sc., Chemistry Department, University of Canterbury (Ph.D. Research Fellow).
- RUSSELL, Graeme Baxter, B.Sc.(Hons.), Chemistry Department, University of Canterbury (Ph.D. Research Student).
- SHEAT, Sylvia Vine, M.Sc., Chemistry Department, University of Auckland (Temporary Junior Lecturer).
- SUTHERLAND, Graeme John, M.Sc., Chemistry Department, University of Canterbury (Ph.D. Research Fellow).
- WESTON, Rodney Malcolm, B.Sc., Garmac Industrial Investment Ltd., Onehunga (Chemist and Factory Manager).
- WRIGHT, Graham Allen, M.Sc., P.Phil.(Oxon.), Chemistry Department, University of Auckland (Lecturer).
- WRIGHT, Graeme John, B.Sc.(Hons.), Chemistry Department, University of Canterbury (Assistant Lecturer).

#### Resignations

J. B. BRUECKNER, J. S. GEORGE.

#### Leave of Absence

A. F. JOHNSON.

## THE CHEMICAL CONTROL OF PLANT GROWTH

R. H. M. LANGER

*Professor of Plant Science, Lincoln College, University of Canterbury.*

In these days of multi-stage rockets, electronic computers, atomic piles and many other remarkable technological achievements we often tend to forget two very important things which we would do well to think about for a moment or two. The first is that all the marvels of the atomic age are the end products of a long and arduous process of scientific study which began very many years ago with quite simple and, at the time, seemingly not even important observations. The other is that in many other fields of human endeavour equally exciting events have taken place. These events may not always have hit the headlines with the same regularity as space flights, which the newspapers describe in such dramatic detail, but they are nevertheless equally spectacular advances which in their particular sphere have brought about revolutionary changes in thought and in practice.

It is the tremendous progress in our knowledge of plant growth control and its application to agriculture and horticulture that I want to describe in this paper. It is a subject which has all the ingredients of one of the greatest success stories in biological science. Starting with quite simple observations, which aroused the curiosity of enquiring minds and led to a great number of painstaking experiments in many laboratories, it has culminated in the development of techniques of far-reaching practical significance.

### *DISCOVERY OF GROWTH SUBSTANCE*

Many of you will know the joke about the man who planted bean seeds in his garden, only to be told that he had planted them upside down, whereupon he dug them all up again and turned them over. From your own experience you know, of course, that this man need not have wasted his time because the seeds would have grown well enough whichever way they had been planted, but have you ever given any thought to this simple phenomenon? Why do roots always grow down and shoots always grow up? There is another observation that you must all have made or seen demonstrated as a class experiment. If you grow a pot plant in a room it will always turn towards the light. Have you ever wondered why this should be so in a plant of all things which has no eyes and no nervous system?

Even if you have never given any thought to these everyday occurrences, there was a man about 80 years ago who did. He was none other than Charles Darwin, the celebrated founder of the theory of evolution. He was experimenting with a species of grass used for

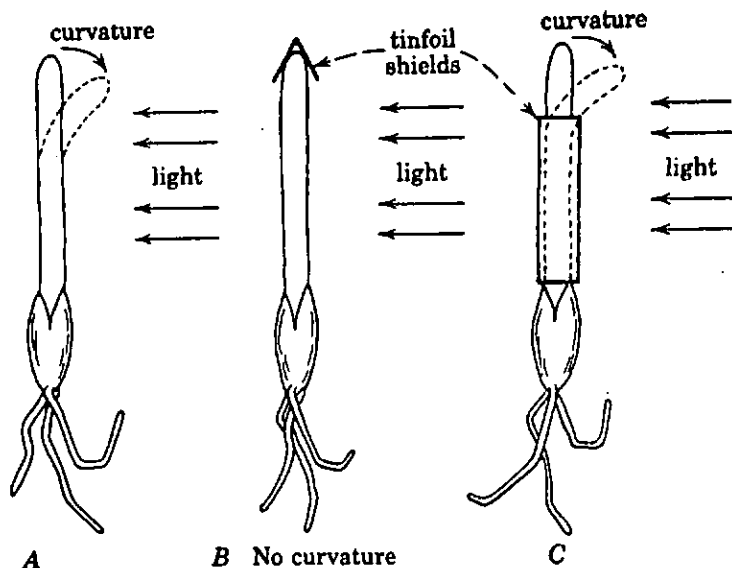


Fig. 1: Effect of unilateral light on phototropic curvature of coleoptiles. A: not covered; B: tip covered; C: covered below tip. (From Robbins, Weier and Hocking, Botany: An Introduction to Plant Science, John Wiley and Sons, Inc., N.Y.)

ornamental purposes. In common with all other grasses, his seedlings produced, upon germination, a small sheath-like organ, the *coleoptile*, which he found to be extremely sensitive to light, or, as we would say today, it was *positively phototropic*. (Fig. 1.)

If the tip of these coleoptiles was covered with tinfoil, they no longer bent towards the light, and from this Darwin argued that it was the tip of these organs that perceived the light stimulus. The actual bending, on the other hand, occurred lower down on the coleoptile, so that he felt justified in concluding that some influence engendered by light in the tip must have been transmitted to the growing regions lower down. Darwin described his observations in a book called *The Power of Movement in Plants*, but for over 30 years following its publication no significant progress was made. Then a Danish scientist, Boysen Jensen, showed that it was possible to get coleoptiles to bend towards the light, even after their tip had been cut off but re-attached by means of a thin coat of gelatin. (Fig. 2.) In other words, the union of living cells was not necessary for the unknown stimulus to travel from the tip to the curving region below. The identity of this stimulus was still anything but clear, and electrical currents and even the presence of some sort of nerves were seriously considered.

The next big advance came from experiments performed by Paal, a Hungarian, who cut off coleoptile tips and then replaced them on one side of the stump. In the absence of any unilateral light the coleoptiles were induced to grow faster on that side and thus to curve the other way. The only tenable interpretation of these results, which was put forward by Paal, was that the coleoptile tip produced a chemical growth-regulating substance which normally was equally distributed. Unilateral light appeared to cause a redistribution towards the darkened side, thus making it grow longer, and, of course, replacing a coleoptile tip asymmetrically also resulted in a curvature.

The stage was now set for the isolation of this powerful substance. Credit for this achievement goes to F. W. Went, a Dutchman, working in his father's laboratory at Utrecht. Instead of replacing the detached coleoptile tips on the stumps, Went left them standing on blocks of sterile agar, a non-living material. After a while, these agar blocks on their own were planted asymmetrically on coleoptile stumps in the dark, and in due course curvature was observed on the side on which the little blocks had been placed. This demonstrated beyond doubt the ability of the coleoptile tip to produce a growth-stimulating substance which was able to diffuse into a block of agar and later out again into a coleoptile stump. Went continued his experiments and eventually devised a method which enabled him to measure the amount of growth substance by the degree of curvature it produced.

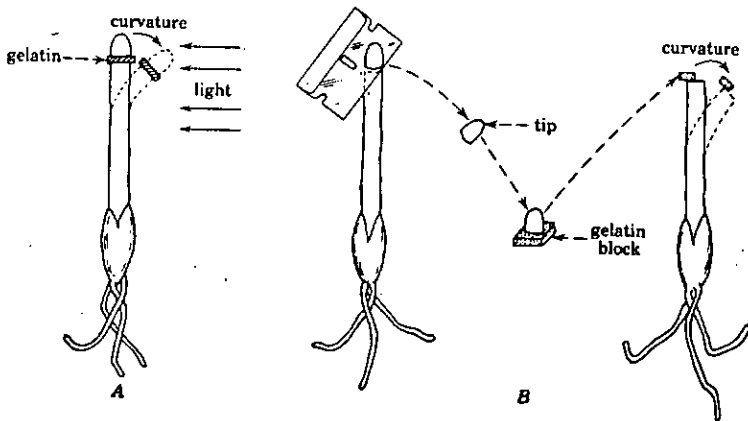


Fig. 2: A: phototropic curvature after the coleoptile tip has been re-attached with gelatin; B: coleoptile tip left in contact with block of gelatin or agar. Block placed eccentrically on stump causes curvature in the dark. (From Robbins, Weier and Hocking, Botany: An Introduction to Plant Science, John Wiley & Sons, Inc., N.Y.).

The hunt was now on to determine the chemical nature of this powerful substance. Went had shown that it could be extracted from coleoptile tips, but in course of time other tissues were also found to contain similar activity. Again it was in Holland that success was achieved. F. Kogl and his collaborators managed to isolate and identify three active substances, of which the most important was a simple and well-known organic compound, 3-indoleacetic acid. We now know that this acid is widely distributed in plants. Relatively high concentrations are found in actively growing regions, particularly in shoot tips, young leaves, pollen, young ovules and fruits, as well as in cotyledons. Insofar as 3-indoleacetic acid in minute quantities is produced in certain regions of a plant and because it may move and affect growth in other regions, it complies with the definition of a hormone. But the fact that it is such a simple substance which can be synthesized quite easily enabled scientists all over the world to study its effects on plant growth in an intensive programme of work.

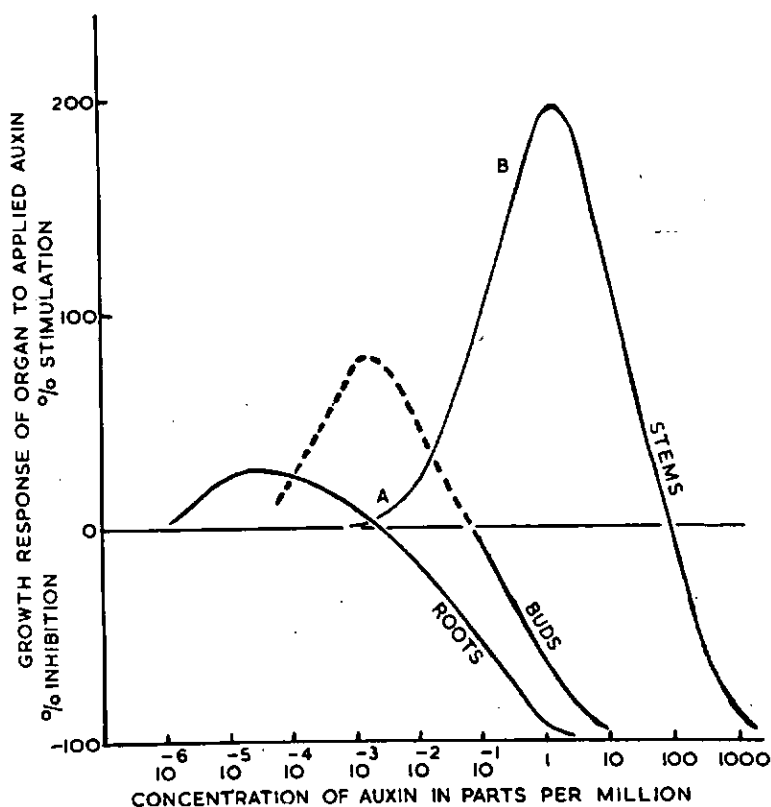


Fig. 3: The effect of growth substance depends on its concentration. (From *Audus, Plant Growth Substances, Leonard Hill, Lond.*)

One of the most important discoveries made was that the effect of indoleacetic acid depended on its concentration (Fig. 3). Up to a certain value, growth was found to be increasingly promoted as the level of the substance was raised, but beyond this value the response declined, until eventually growth was retarded. Growth promotion could thus be turned into inhibition. Furthermore, stems, buds, and roots were found to differ in their sensitivity to indoleacetic acid. A solution which stimulated stems, for example, turned out to be far too concentrated for roots and tended to inhibit their growth. Thus, the growth of plants is governed by a very delicately balanced mechanism of hormonal control, and this will become even more apparent after I have described other regulators which we have reason to suspect occur naturally in plants.

First, let us briefly reappraise the kinds of plant movement which I mentioned at the beginning of the paper. We know now that growth substance is produced in the coleoptile tip from which it moves equally to regions lower down. Light on one side causes an accumulation of substance on the darkened side, and it is there that the cells elongate to a greater extent, thus producing a curvature towards the light. But how can the fact be explained that roots grow down (they are said to be *positively geotropic*), while shoots are *negatively geotropic* and thus grow up? Again we are dealing with a redistribution of growth substance which tends to accumulate on the lower side of a horizontally placed shoot causing greater elongation in the cells there and consequently upward bending. In roots it is thought that the same kind of growth substance movement suppresses cell elongation on the lower side because as we have seen roots are more sensitive than shoots.

There is one other point to be clarified before proceeding: the meaning of the term, *auxin*. This name was given originally by Kogl to two growth substances which he thought occurred naturally. In modern usage, however, auxin is a generic term for a compound which induces cell elongation in shoots. Indoleacetic acid would therefore be classified as an auxin. This compound, by the way, is often referred to by its abbreviation IAA.

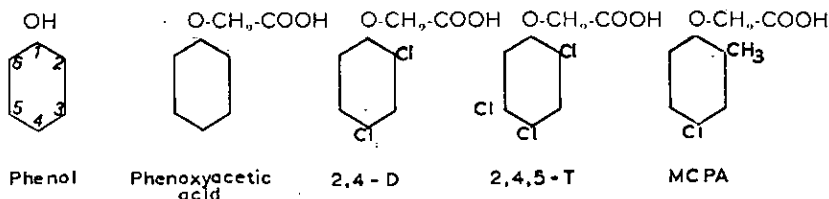
### SYNTHETIC PLANT REGULATORS

Once it was known that IAA had such an important function in regulating growth and other plant processes, and because this substance could easily be prepared synthetically, the chemist came to the aid of the plant physiologist and joined in the search for other compounds with similar activity. The first step was to investigate a number of derivatives and homologues of 3-indoleacetic acid. Many of these, for example 3-indolebutyric acid and 3-indolepropionic acid, were found

to induce cell elongation in the coleoptile, in much the same way as IAA had done, the main difference being that these were entirely synthetic substances which, to the best of our knowledge, do not occur naturally in plants.

These successes encouraged scientists to look further afield for active compounds. In any case the relatively high cost of indole derivatives looked like placing a limitation on their large-scale use as plant regulators. Other compounds not containing an indole ring were therefore investigated. One of the first to produce considerable response in plants was alpha-naphthalene acetic acid (NAA), and in addition other naphthalene derivatives were also found to be active.

Perhaps the most fortunate discovery, which eventually had such an enormous impact on agriculture, was that many phenolic compounds had an effect on plants. Among these, phenoxyacetic acid was found to have a stimulating effect on plants but, more important, activity could be greatly increased by substituting certain hydrogen atoms with other atoms or groups, especially halogen and methyl groups. The compound to achieve the greatest fame because of its wide use in agriculture and horticulture, was 2,4-dichlorophenoxyacetic acid or, as it is more commonly known, 2-4D. I hope that these long names do not worry you unduly and that you will attempt to become familiar with the full name, which is so much more informative than the abbreviated version. In the present example we are dealing quite simply with a number of substitutions. From phenol we go first of all to phenoxyacetic acid and, following that, we exchange two hydrogen atoms for two chlorine atoms, the only complication being that we have to indicate the place of these substitutions on the ring by the numbers 2 and 4.



If you understand this simple system, you will have no difficulty in visualizing and remembering two other important phenolic growth regulators, namely, 2,4,5-trichlorophenoxyacetic acid (2,4,5-T) and 2-methyl-4-chlorophenoxyacetic acid (MCPA). Both compounds have found wide application in agriculture. Quite often one does not use the acids as they are, but their sodium or ammonium salts or amines produced from them. This is done mainly to improve solubility.

Over the years an ever increasing number of compounds which have some activity when applied to plants have been discovered. Many of them comply with our definition of an auxin, but there are others, like the carbamates, which upset cell division, while others injure all plant tissue with which they come into contact.

### *MODE OF ACTION OF PLANT REGULATORS*

You will appreciate that this great multiplicity and variability of the auxins alone immediately gives rise to a very important and difficult question. If compounds of such chemical diversity can have basically similar effects on plants, what properties do they all share which enable them to be growth regulators? What, in fact, is the key to their magic? An unequivocal answer to this question would quite clearly be of tremendous importance, for it would indicate what other compounds should be investigated in a search for more powerful, more specific and less costly growth substances.

Until a few years ago there was thought to be a reasonably good answer, but more recent work has cast considerable doubt on these theories. All that can be said now with a reasonable degree of certainty is that a substance must comply with at least the following requirements if it is to act like an auxin:

- (1) The molecule must have an acid group.
- (2) It must have an aromatic ring or an arrangement of atoms equivalent to a ring.
- (3) The acidic group must be able to assume a position outside the plane of the ring, and
- (4) There must be a certain balance in the affinities of the molecules for aqueous and fatty substances.

Beyond these four premises we cannot go with any certainty, at least for the time being.

We are also beginning to see the likely mechanism of auxin action. Try to visualize the cytoplasm of a plant cell as a highly organized network, composed in its final detail of interlacing chains of molecules. Within this network there are tiny slots which will receive molecules of appropriate size and reject those which are too large in one or more dimensions. It is thought that the acidic group of an auxin molecule provides the missing link, as it were, which completes the network, and that in consequence the events typical of auxin action are set in motion, without necessarily involving any chemical reaction of the auxin molecule itself. However, some of these ideas are still highly speculative and vague. There is certainly no danger that, by the time some of you will have reached the stage of making a contribution to science, nothing will remain to be discovered!

## PRACTICAL APPLICATION OF PLANT REGULATORS

Although knowledge of how these active compounds actually work is still far from complete, it has been learned, largely by trial and error, how to harness them in the service of agriculture and horticulture. From the small beginnings, which I have described to you, there has been witnessed in our own generation the fantastic growth of an industry worth many millions of pounds producing a multiplicity of synthetic plant regulators without which modern farming would appear to be almost unthinkable. Let me enumerate and briefly describe some of the many applications of these substances: promotion of roots, control of fruit setting, production of seedless fruits, thinning of blossoms, inhibition of sprouting and, probably most important of all, chemical weed control.

### *Promotion of roots*

In horticultural practice it is quite common for plants to be propagated by the taking of cuttings. Portions of a plant, mainly stems of suitable age, are cut and placed in a favourable medium in the hope that roots will be produced, the intention being of course to obtain new plants from the original one from which the cuttings were removed. This method of propagation is very common for hedge plants, such as privet and yew, and also flowering shrubs, for example, hydrangeas.

The important point is that in the stems of most plants there are no cells which would normally produce roots. However, under favourable conditions some cells can be induced to form root primordia, and this process can be greatly speeded up through the action of certain plant regulators. Among these, 3-indolebutyric acid and alpha-naphthaleneacetic acid have found the widest application. The treatment of cuttings normally takes one of these forms: soaking the ends of cuttings in dilute auxin solutions for something like 24 hours, dipping in more concentrated solutions for a matter of seconds or minutes, or the application of talc containing auxin. The concentration of the active compound is critical for, as by now you should be able to predict, root growth can easily be inhibited. Exactly how the auxins work is still largely unknown. The cuttings of many species do not respond, so, once again, a great deal of research work is still needed.

### *Control of Fruit Setting*

Each autumn the continual fall of leaves can be witnessed, and you will have noticed how, prior to this, fruit trees shed many of their blossoms and young fruits. This process, called *abscission*, occurs commonly and often regularly in many plants. If one examines the petioles of leaves towards autumn, one finds that a special abscission zone

composed of small, closely packed cells has been developed. In due course the cells in this zone separate, with the result that the leaf is shed.

Careful study of the physiology of the process has shown that auxins are once again deeply involved. Let us carry out an imaginary experiment. Suppose that we cut off a healthy leaf. Before long we would find that the petiole will form an abscission layer and that it will drop off in course of time. But if we apply 3-indoleacetic acid to the petiole, abscission will be greatly delayed. Auxins, it would thus appear, have the power of delaying this process. Supporting evidence comes from the analysis of natural auxins in fruits. If we were to determine the auxin content of a developing fruit, we would find that initially quite appreciable amounts are present but that, as the fruit matures, the content decreases until finally the fruit drops. From this and many other experiments it can be concluded that abscission of an organ is prevented as long as its auxin supply is high, but that a decline in the level of auxin allows the formation of an abscission layer leading ultimately to the shedding of the organ.

A number of other factors, such as water supply and the level of carbohydrates, are also involved, but the action of auxins is sufficiently strong to enable leaf and fruit fall to be delayed or prevented in many plants by spraying them with synthetic growth regulators. Alpha-naphthaleneacetic acid and 2,4-dichlorophenoxyacetic acid in very dilute solutions have been found effective in certain varieties of pears and apples. Peaches and apricots, on the other hand, have proved singularly unresponsive. This difference among species alone should demonstrate to you how much more we have yet to learn about the action of auxins. To make matters even worse, auxins may under certain conditions have the very opposite effect insofar as they can promote the shedding of blossoms. The mechanism in this case is quite different, because it is believed that in part at least applied auxins may prevent natural pollination and may also cause the young embryo to abort. Both these events tend to inhibit the production of natural growth substance in developing fruits and this, as we have already seen, speeds up the formation of an abscission layer. Whatever the precise explanation, practical use can be made of this information by using synthetic plant regulators at suitable concentrations for the thinning of blossoms, if it is found that fruit trees are carrying a greater number than they can effectively develop.

#### *Production of Seedless Fruit*

We have just learned that young fruits have a high auxin content. If we enquire why they should be so richly endowed, we discover that it is the act of pollination which gives rise to a great increase in

the auxin content of the ovary and that this auxin is the immediate cause of fruit-set. This contention can be tested by applying a pollen extract to the ovary or, better still, a dilute solution of synthetic auxin. In either case, provided other conditions are favourable, a fruit will develop in suitable species even though pollination has not taken place. Such fruits are called *parthenocarpic* and do not contain any normal seed, although in some instances the seed coat alone may be developed. Tomatoes, melons, figs and other plants have been treated successfully in this way, often on a commercial scale.

#### *Inhibition of Sprouting*

Large quantities of potatoes, onions, carrots and other vegetables are lost during storage every year, because sooner or later they start sprouting, and this is followed by loss of water and shrivelling. This resumption of growth could be greatly delayed by storing at low temperatures below 40°F, but under many conditions this would be extremely difficult and even undesirable. Once again, scientists have turned to auxins as a possible agent for the control of this process. As we have seen, the effect of growth substances is governed by their concentration: plants may be stimulated to grow or be retarded, depending on the amount that is applied. If, as in this instance, the aim is to prevent growth, one would naturally turn to fairly concentrated solutions for the control of sprouting in stored potatoes or carrots. Considerable success has in fact been achieved on a commercial scale at low cost and with highly rewarding results.

#### *Chemical Weed Control*

The control of weeds has become the most important and widespread application of auxins, since its discovery in Britain and the United States during the last war. Before then chemicals were used as herbicides, but their action depended mainly on their ability to burn the leaves of plants. However, the advent of synthetic auxins coupled with the knowledge that at high enough concentrations they can inhibit growth has brought about a change of revolutionary magnitude, particularly for two reasons. First, auxin weedkillers are translocated throughout the plant and thus are effective outside the area of immediate contact, and, secondly, these substances are selective in action. Thus flat weeds can be killed in a stand of wheat, for example.

This question of selectivity is an important and highly involved problem. Some factors are easily discernible, such as the difference in habit between dicots and monocots which makes the former more easily damaged by sprays. But this is only one of many aspects. There are many other differences among plant species which would affect their response to applied auxins: the amount of spray which is retained on the leaf surface, the ease of penetration into the leaf, the

degree and speed of translocation, the stage of growth of the plant, or even some differences in the nature and sequence of biochemical reactions. This list does not exhaust the possibilities by any means—once again a reflection of our ignorance of how auxins really work inside the plant.

By far the most important weed killers so far have been 2,4-D or its salts, esters and amines, and also 2,4,5-T, all usually disguised by a carefully chosen trade name. These chemicals have enabled many weeds which were reducing crop yields to be controlled. An even greater degree of selectivity has been achieved in recent years, based on the discovery that beta-oxidation occurs in many, but not in all, plants. In the fatty acids the number of methylene groups can be added to and in this way we can arrive at a series from acetic acid with one such group to propionic acid with two, butyric with three, valeric with four, caproic with five, heptanoic with six, and so on.

Acetic  $\text{CH}_3\text{COOH}$ ;

Propionic  $\text{CH}_3\text{CH}_2\text{COOH}$ ;

Butyric  $\text{CH}_3(\text{CH}_2)_2\text{COOH}$ ;

Valeric  $\text{CH}_3(\text{CH}_2)_3\text{COOH}$ .

In much the same way the chemist can build up a series of acids starting with phenoxyacetic, complete with the two chlorine substitutions as in 2,4-D. Inside many plants these chains of carbon atoms are reduced in length, two carbons at a time, by enzyme action, so that acids with an odd number of methylene groups would eventually be degraded to the acetic derivative, and it is this compound which is active as a weedkiller. Some crop plants do not appear to have the appropriate enzyme system, and so they can be sprayed quite safely with, say, 2,4-dichlorophenoxybutyric acid, but some weeds, such as creeping thistles, break this compound down to 2,4-D and can thus be killed. There are, in addition, numerous other examples which demonstrate that knowledge of the beta-oxidation system has helped us to extend the range of selectivity enormously.

#### *PLANT REGULATORS OTHER THAN AUXINS*

Because I have attempted to present to you a continuous narrative, I have so far not mentioned a whole host of substances which, although not auxins, have most startling effects on plant growth. Many of them are used as weedkillers, notably a group of compounds, the carbamates, which disrupt normal cell division, and also chlorinated aliphatic acids, of which the most important is 2,2-dichloropropionic acid, better known as dalapon. In fact, the combined efforts of the chemist and the plant scientist have provided a most powerful array of substances which have put hitherto quite unthinkable methods of control within grasp.

One group of compounds deserves special mention. These are the gibberellins, named after a fungus in which they were first discovered. Recent evidence indicates that substances belonging to this group occur naturally in higher plants and that their importance in the regulation of growth is very great. In fact, it is now thought that plant growth is controlled by a whole range of inter-relating hormones, of which mainly indoleacetic acid and gibberellin have so far been identified with certainty. The effect of externally applied gibberellin is very marked, for the plant responds by extreme elongation of internodes, and in some species by the production of flowers (Fig. 4).

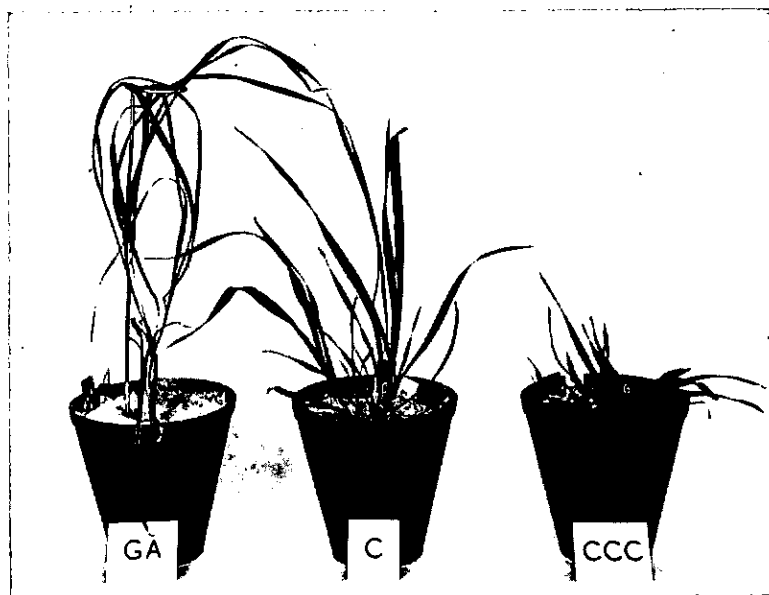


Fig. 4: Effect of gibberellic acid (GA) and CCC on prairie grass compared with control plant (C).

Among the latest additions to the swelling ranks of synthetic plant regulators are the quaternary ammonium compounds. For example, a substance related to this group named (2-chloroethyl) trimethylammonium chloride (CCC), has properties which in many ways are the exact opposite of those of the gibberellins. Internode length is reduced, the foliage becomes a darker green and, in some cereals at least, more lateral shoots are produced.

As we have seen, the science of chemical plant growth control has developed tremendously over the last thirty years or so, since Went demonstrated that the tips of coleoptiles produced a diffusible growth substance. Literally hundreds of chemical compounds have

been discovered which in some way or other stimulate, retard or generally modify plant growth and other processes. Many of these compounds have been put to practical use to a degree which has changed the face of agriculture and horticulture profoundly. What better example of "Chemistry in Action" could there be? At the same time, the very advent of this multiplicity of active substances has provided us with the tremendous challenge for the future of discovering the ultimate mechanism of their action. A great deal of research has yet to be done.

I hope that some of you will feel inspired to "follow knowledge like a sinking star beyond the utmost bound of human thought".

#### BOOKS FOR FURTHER READING

- AUDUS, L. J., *Plant Growth Substances*, Leonard Hill, 1959.  
LEOPOLD, A. C., *Auxins and Plant Growth*, Univ. Calif. Press, 1955.  
MATTHEWS, L. J., *Chemical Methods of Weed Control*, Dept. Agric. N.Z., Bull. 329, 1960.  
TUKEY, H. B. (ed.) *Plant Regulators in Agriculture*, J. Wiley & Sons, Inc., 1954.

---

#### CHEMISTRY IN ACTION

The three papers published in this issue are based on the 1962 "Chemistry in Action" addresses arranged by the Canterbury Branch and delivered to sixth form pupils in Christchurch earlier this year. These papers will be issued in booklet form for sale to secondary schools.

## NEW FUNCTIONS FOR VITAMINS

MICHAEL H. BRIGGS

*Lectures in Biochemistry, Victoria University of Wellington.*

Many of you will be beginning university courses next year, and part of the function of these papers is to break you very gently into university work. In fact, they can be regarded as a kind of cocktail before your academic feast. To ensure that my cocktail is nutritious I am going to make it of vitamins.

It is no coincidence that all three papers this year are on biochemical subjects. Biochemistry is bursting forth at such a rate that no one can hope to keep track of more than a small amount of new work. For this reason, I have decided to tell you not about things that are well known, but about research work that is actually in progress. To be lazy I am going to tell you about my research: about problems that are still largely unsolved. I hope that you will find this more stimulating than hearing of work that is completed and finished.

I am going to touch on several problems, all connected in some way with vitamins.

Vitamins were discovered by nutritionists, who found that the more they purified an animal's diet, the more unhealthy it became. All vitamins are organic compounds that play essential roles in the chemical reactions of living cells. They are needed in the diet because the body cells lack the ability to make them. However, this paper is not about vitamin nutrition but about the functions they serve in tissues, and the defects that result when a vitamin is lacking. As I cannot hope to deal with all the vitamins, or even with any one thoroughly, I am merely going to select some new issues that have interested me.

### *VITAMIN A IN VISION AND ITS OTHER ROLES*

When an animal is raised on a diet lacking vitamin A, its tissues become seriously disordered. Its skin becomes rough and scaly. It slowly becomes blind and unable to detect odours, and finally dies. To investigate the function of vitamin A in tissues other than the eye has proved very difficult, so I will first deal with the role for vitamin A in vision.

If one examines the eye of an animal that has been raised on a diet lacking vitamin A, one thing is very apparent. There is no pigment in the retina.

It is possible to extract the visual pigments of an animal's eyes and examine them in the laboratory. The animal is kept in the dark for several hours before the experiment and is then killed. All the following procedures must be conducted in darkness. The eyes are removed

and extracted with a 2% solution of digitonin. This brings out all the visual pigments. The resulting solution is darkly coloured, but soon bleaches when exposed to light. It is fairly easy to discover the chemical reactions that happen as the visual pigments bleach. If one extracts the *unbleached* solution with ether, nothing much is extracted, but extracting the *bleached* solution gives an interesting result. The ether extract contains quantities of vitamin A aldehyde. This substance, which is usually called *retinene*, has been released from the visual pigment by the action of the light, and all that is left in the solution after ether extraction is a protein called *opsin*.

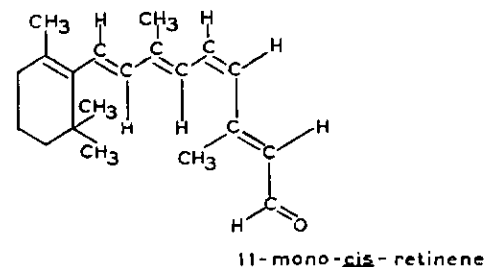
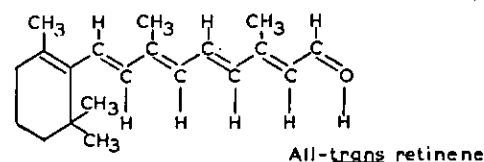
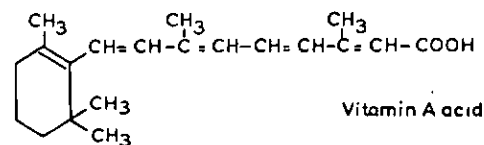
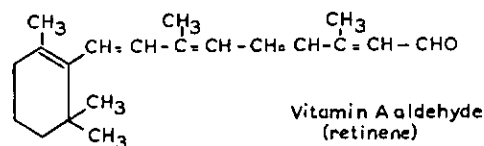
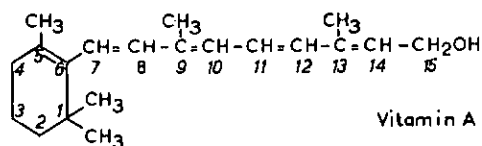


Fig. 1: Vitamin A and related compounds.

The intact visual pigment is a compound of opsin and retinene (called *rhodopsin*). The exact way in which the two parts are linked together is still not fully understood.

Studies of the bleaching of rhodopsin from animals such as rats have been undertaken at very low temperatures, and it has been discovered that there is an intermediate between rhodopsin and opsin and retinene. This intermediate is called *meta-rhodopsin*. To understand the nature of this substance it is necessary to look at the structures of vitamin A and retinene (Fig. 1). You will see that there are several double bonds in the side chains. At each there is the possibility of geometrical isomerization; that is, the existence of two forms—*cis* form if hydrogen atoms on adjoining carbons linked by the double bonds are on the same side of the carbon chain, or *trans* form if they are on opposite sides. The interesting question is, which geometrical isomer is involved in the visual pigment? The vitamin A present in all tissues of the body, except the eye, is the all-*trans* form. The retinene extracted by ether from a bleached solution of rhodopsin is also all-*trans*, but the retinene in the eye (and in rhodopsin) is the 11-mono-*cis* form.

It is now possible to understand the bleaching of rhodopsin. When light strikes the molecule the retinene part alters its geometrical shape. It flips from a *cis*- to a *trans*-form. That is all that happens chemically in vision. The product is *meta-rhodopsin*. But it so happens that this is an unstable substance that readily hydrolyses to give free retinene and opsin. These changes are shown in Fig. 2.

It occurred to us at Victoria University of Wellington (and also to other biochemists elsewhere) that maybe the *meta-rhodopsin* from some animals is more stable than that from others. In all mammals the *meta-rhodopsins* are very unstable, but in the octopus and squid they are quite stable. They are very stable also in crabs and lobsters and may be stored and studied for several hours without decomposition. On the other hand, in insects and spiders the *meta-rhodopsins* are unstable.

One very striking fact is that exactly the same chemical system of vision is used by all animals with eyes.

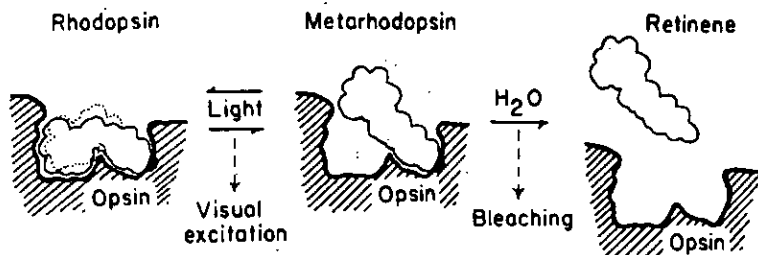


Fig. 2: Diagrammatic representation of changes in visual pigments.

Although the role of vitamin A in the eye is understood, its function in other tissues is not. So far two approaches have been made to investigate these other functions.

It is fairly easy to oxidize vitamin A to retinene and then further to vitamin A-acid. This latter compound is not reducible in the body. Very interesting changes occur in experimental animals deprived of vitamin A, but given vitamin A-acid. The most obvious change is that they become blind, but they also become sterile. Male rats fail to produce sperm. Female rats can become pregnant, but resorb their foetuses.

Apart from these changes the animals grow well and look quite healthy. Their tissues do not show the changes found in vitamin A-deficient animals. These results show that, whatever the function of vitamin A in most tissues may be, and this is not known, it does not involve the alcohol grouping of the side chain (except perhaps in the reproductive organs).

The other role for vitamin A concerns the sense of smell. Occasionally, after a bad attack of influenza, persons lose their sense of smell. There is nothing apparently wrong with the nose, it just is not working. Such cases of uncomplicated anosmia, as they are called, turn up fairly regularly. It has been found that if such a patient is given several large doses of vitamin A by intramuscular injection, the sense of smell almost always returns. Now why is this? These persons are not deficient in vitamin A, so that is not the reason. I do not know the answer.

But perhaps this explains something I mentioned earlier. Experimental animals deficient in vitamin A lose their sense of smell, so it is clear that the vitamin functions somewhere in the epithelium of the nose, which is responsible for odour reception.

Very little is known about the chemistry of smell. One widely-held theory is that the odour of any compound is related to its molecular vibrations. Perhaps vitamin A, or some related substance, in the lining of the nose can be altered by the vibrations of any molecule with which it collides. In this way smells are detected, but this is an untested hypothesis. On the whole, ignorance in this field is appalling.

#### *VITAMIN C AND SCHIZOPHRENIA*

I want to turn now from vitamin A to vitamin C. There are very few animals unable to manufacture ascorbic acid; the list includes man, monkeys, guinea-pigs, desert locusts, marmots, fruit bats and the red-vented bul-bul. All other animals can make vitamin C from sugars.

I would like to suggest that there is some relationship between ascorbic acid and schizophrenia. I may be quite wrong, but at least by describing this work I can show you a little about scientific research actually in progress.

First I want to outline a little of what is known of chemical changes in schizophrenics. Schizophrenia is a very serious disease. About one person in every 100 is affected, at least partially. The symptoms in severe cases include weird hallucinations and delusions of persecution or of grandeur. Moreover, the patient becomes withdrawn and then has phases of excitement that are frightening to relations and friends. The disease develops generally in young adults, though older and younger cases are known.

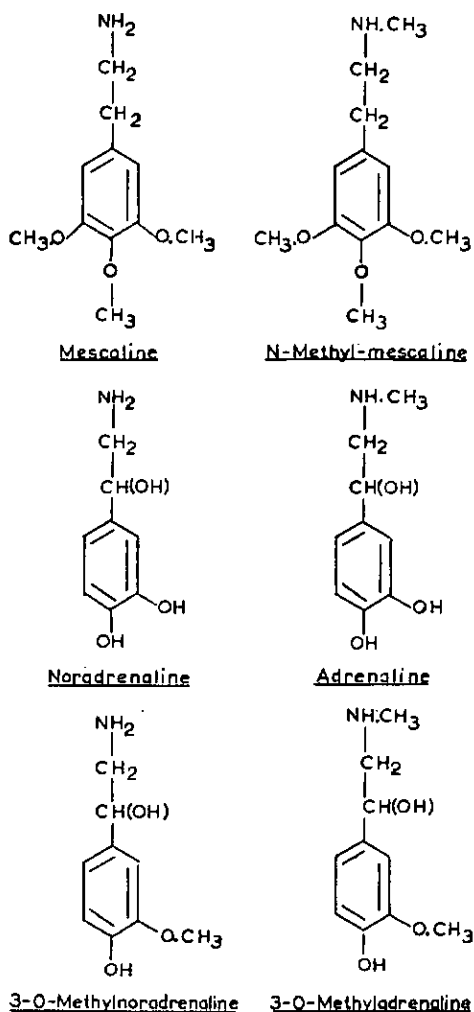


Fig. 3: Mescalines and adrenalines.

Let us consider first the hallucinations and delusions. It is possible to produce very similar mental states in normal people by giving certain drugs, for example, mescaline or N-methyl-mescaline. Figure 3 shows that there is a close chemical similarity between these drugs and the adrenalines, compounds produced by many nervous tissues including the brain. The similarity is even closer when it is realized that the first step in the breakdown of adrenaline or nor-adrenaline in tissues is O-methylation.

It is known that adrenaline solutions do not keep very well. They become gradually discoloured and take on a pink shade. If this deteriorated "pink adrenaline" is injected into a normal person it acts as an hallucinogen; just like mescaline. The nature of the compound in "pink adrenaline" that produces the hallucinations is the subject of controversy. Some people think it is adrenochrome, others adrenolutin. The structures of these compounds are shown in Fig. 4. They belong to the group of compounds known as indoles—the essential feature of the structure is a benzene ring joined to a ring of 4 carbons and 1 nitrogen atom. It is probably coincidence that another large group of synthetic drugs that can induce hallucinations in normal people are also indoles.

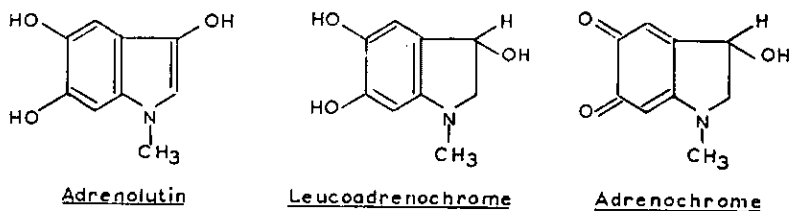


Fig. 4: Oxidation products of adrenaline.

It is conceivable, therefore, that schizophrenics produce in their tissues some abnormal indole compound (perhaps from adrenaline) and that this is responsible for their hallucinations and delusions. But why should they do this? It has been shown that schizophrenics excrete larger quantities of adrenaline in their urine than other people. If their tissues are making too much adrenaline, the occasional presence of abnormal indole breakdown products would not be surprising. But why would they make too much adrenaline?

My hypothesis, which has still to be tested, is as follows. Schizophrenics are known to have higher concentrations of blood copper than normal people. Copper catalyses the oxidation of ascorbic acid. Hence there could well be too rapid a breakdown of vitamin C in the blood of schizophrenics, so that their tissues continually receive insufficient. What would be the result?

Aromatic aminoacids are absorbed from the diet—too many for protein synthesis. Some of the excess is converted to adrenaline, the rest is broken down to CO<sub>2</sub>. The breakdown of two of the excess aminoacids, tyrosine and phenylalanine, needs vitamin C. If there is not enough of this activator an imbalance results in abnormal adrenaline synthesis.

This hypothesis may be wrong, but in experiments conducted at Victoria University we have found high concentrations of ascorbic acid breakdown products in the urine of schizophrenics. We have also found p-hydroxyphenylpyruvate, a compound formed by an impairment of tyrosine oxidation.

To see if our theory is correct we have also begun dosing a group of chronic schizophrenics at the Porirua Hospital with vitamin C. A recent report from England gives us hope that this treatment may have value. A single chronic schizophrenic in a Leicester mental hospital had recently developed scurvy and was given, over a short period of time, 21 grams of vitamin C. Not only did the scurvy disappear, but his mental state also was greatly improved. However, we will have to wait to see whether vitamin C is at all related to schizophrenia. Many more results are needed.

### CANCER AND VITAMINS

I also want to mention the relationship of vitamins to cancer. It is a well-known fact that the concentration of most vitamins in tumours is considerably lower than in normal corresponding tissues. For example, Table 1 shows some results of mine on liver tumours induced in rats by a dye: butter yellow. What do these results mean? And are they of any importance to an understanding of the cancer processes?

Let us consider just one of these vitamins: nicotinic acid. Within a cell, nicotinic acid is rapidly converted to two more complex sub-

TABLE 1: CONCENTRATION OF VITAMINS IN NORMAL LIVERS AND IN HEPATOMAS

Vitamin	Concentration (mean of five determinations) $\mu\text{g/g}$ wet tissue	
	Normal liver	Hepatoma
Thiamine	2.3	1.1
Riboflavin	26	4
Nicotinic acid	160	33
Biotin	0.85	0.17
Total vitamin B6	9.0	2.4
Pantothenic acid	91	9
Vitamin A	45.1	8.5
Tocopherols	38	5.1
Ascorbic acid	20	25

stances: nicotinamide-adenine-dinucleotide (NAD) and nicotinamide-adenine-dinucleotide-phosphate (NADP). The functions of NAD and NADP are well understood. They are coenzymes. That is, they, together with a specific enzyme protein, form a biological catalyst that catalyses just one reaction inside cells.

All reactions catalysed by NAD or NADP and their enzymes are dehydrogenations. Reactions of this sort are of fundamental importance in metabolism for a simple reason. To oxidize reduced NAD or reduced NADP requires a complex series of reactions which in the process converts inorganic orthophosphate to organic phosphate esters. In particular, it converts adenosine diphosphate (ADP) to adenosine triphosphate (ATP). Now the energy for all synthetic reactions in a cell is provided by the breakdown of ATP. Consequently, the formation of ATP by dehydrogenations is the key to all life processes.

TABLE 2: CONCENTRATION OF COENZYMES IN NORMAL LIVER AND IN HEPATOMAS

<i>Coenzyme</i>	<i>Normal liver</i>	<i>Hepatomas</i>
Total NAD ( $\mu\text{g/g}$ wet tissue) ....	480	176
Total NADP ( $\mu\text{g/g}$ wet tissue) ....	230	24
NAD/reduced NAD ....	2.2	2.9

But as I mentioned before, there is very little nicotinic acid in tumour cells. Consequently, there is little NAD and NADP (Table 2). The effects of this on cell metabolism are interesting. The main energy source for all cells is the oxidation of sugars. This oxidation occurs in two stages. First, the conversion of, say, glucose to pyruvic acid. Then, second, the conversion of pyruvic acid to acetic then to  $\text{CO}_2$ . The first stage involves 10 enzymes of which only one is NAD-dependent. The second stage involves 12 enzymes of which 4 require NAD or NADP. It should come as no surprise to you to learn that tumours manage to break down glucose to pyruvic acid quite well, but have difficulty going any further. The result is that pyruvic acid accumulates and most gets converted to lactic acid. This latter reaction also serves to regenerate oxidized NAD.

The search for drugs that will kill cancer cells, but not normal ones, has been in progress for many years. One such drug is 6-mercaptopurine. It has recently been shown that this drug acts by inhibiting the formation of NAD and NADP, so that the concentrations of these compounds in tumours, already low, are reduced to almost nothing and the cells die.

It is my belief that a basic understanding of the origins of tumours is to be sought through research into their vitamins and coenzymes.

#### INSECT MUSCLES

The last topic I want to mention is also closely connected with the dehydrogenases.

When a muscle contracts, sugars are converted to pyruvic acid and then to lactic acid. No further breakdown occurs until the muscle relaxes. Then the lactate is converted back to pyruvate which in turn is changed to  $\text{CO}_2$ . It is quite clear that the key enzyme of muscle contraction is the one which interconverts lactic and pyruvic acids. This enzyme is called lactate dehydrogenase (LDH) and its coenzyme is NAD.

At Victoria University we have recently become interested in insect muscles. These muscles are among the most efficient in the animal kingdom. The flight muscle in particular is extremely efficient.

We have measured the amounts of nicotinic acid, NAD and LDH in a variety of insect muscles. The results are most interesting. We find that flight muscles contain almost no LDH (Table 3), though leg muscles do. It seems that insect flight muscles are able to completely burn up sugars all the time without accumulating lactic acid, though the leg muscles are more like the muscles of a mammal.

TABLE 3: RELATION OF ENZYME CONCENTRATION TO INSECT HABITS—I

Insect	Type	Lactate dehydrogenase units/g fresh weight		
		Flight muscle	Thoracic muscle	Leg muscle
Katydid	Winged (poor flier)	12	—	127
Praying mantis	Winged (mod. flier)	9	—	13
Stick insect	Wingless	—	293	344
Weta	Wingless	—	119	78

In the place of LDH the flight muscles contain large amounts of another enzyme that is of little importance in other muscles. This enzyme is  $\alpha$ -glycerophosphate dehydrogenase (GPH). We have measured the amounts of this enzyme in flight, and leg muscles from several insects with different locomotory habits. Our results are given in Table 4. You will see that the enzyme concentrations are closely related to the insect's flying and walking habits.

Work of this kind is still in its infancy and much remains to be done on the coenzymes and dehydrogenases of muscles (and other tissues) from many more animals.

TABLE 4: RELATION OF ENZYME CONCENTRATION TO INSECT HABITS—II

Insect	Locomotory habits	$\alpha$ -Glycerophosphate dehydrogenase units/g fresh weight	
		Flight muscle	Leg muscle
Bumble-bee	Strong flier	4500	2200
Praying mantis	Moderate flier	1090	175
Katydid	Poor flier	855	85

The number of unsolved problems concerning vitamins is enormous and I have touched on very few. But I hope that perhaps I may have stimulated some of you into wondering about these problems and perhaps in later years you may find the answers that now elude us.

## BIBLIOGRAPHY

## VITAMIN A

1. MOORE, T. (1957): *Vitamin A*. Elsevier: Amsterdam.
2. WALD, G. (1960): Distribution and Evolution of Visual Systems. *Comparative Biochemistry*, 1: 311; Academic Press: New York.
3. DOWLING, J. E., and WALD, G. (1960): Biological Function of Vitamin A Acid. *Proc. National Academy of Sciences [U.S.A.]*, 46: 587.
4. BRIGGS, M. H. (1961): Visual Pigment of Grapsoid Crabs. *Nature*, 190: 784.
5. DUNCAN, R. B., and BRIGGS, M. H. (1962): The Treatment of Uncomplicated Anosmia with Vitamin A. *Am. Med. Assoc. Archives of Otolaryngology*, 75: 116.

## VITAMIN C AND SCHIZOPHRENIA

1. BRIGGS, M. H. (1961): Biochemistry of Schizophrenia. *Science and Culture*, 27: 316.
2. BRIGGS, M. H. (1962): Possible Relations of Ceruloplasmin, Ascorbic Acid and Toxic Aromatic Metabolites in Schizophrenia. *N.Z. Med. Journal*, 61: 229.
3. SPRINCE, H. (1961): Indole Metabolism in Mental Illness. *Clinical Chemistry*, 7: 203.
4. SANKAR, D. V. S. (ed.) (1962): Some Biological Aspects of Schizophrenic Behaviour. *Annals of the New York Academy of Sciences*, 96: article 1.
5. BURNS, J. J. (ed.) (1961): Vitamin C. *Annals of the New York Academy of Sciences*, 92: article 1.

## VITAMINS AND CANCER BIOCHEMISTRY

1. GREENSTEIN, J. P. (1954): *Biochemistry of Cancer*. Academic Press: New York.
2. MINER, R. W. (ed.) (1947): Nutrition in Relation to Cancer. *Annals of the New York Academy of Sciences*, 49: article 1.
3. AISENBERG (1961): *Glycolysis and Respiration of Tumours*. Academic Press: New York.
4. BRIGGS, M. H. (1960): Vitamin and Coenzyme Content of Hepatomas Induced by Butter Yellow. *Nature*, 187: 249.

## ENZYMES AND COENZYMES OF INSECT MUSCLES

1. GILMOUR, D. (1961): *Biochemistry of Insects*. Academic Press: New York.
2. KITTO, G. B., and BRIGGS, M. H. (1962): Lactate Dehydrogenase in Some Insect Muscles. *Nature*, 198: 1003.
3. KITTO, G. B., and BRIGGS, M. H. (1962): A Relationship Between Locomotory Habits and Enzyme Concentration in Insects. *Science*, 135: 918.

## CHEMISTRY AND FOOD TECHNOLOGY

J. K. SCOTT

*Professor of Food Technology, Massey College, Palmerston North.*

## FOOD TECHNOLOGY AS A PROCESS INDUSTRY

*Technologies*

The word technology classically refers to a "description or treatise on one or more of the useful arts"; some of the traditional useful arts are the trades of the smith, the potter, the weaver, the dyer and the miner. Today, the word technology refers to a host of professions relating to our material existence, *e.g.*, in the manufacture of soaps, paints, paper, rubber, food and metals; and the treatment has changed from descriptive to that of applied science. Professional entry to a technology today is best through the appropriate sciences and engineering (combined with a leavening of the dependent humanities) to give an understanding and a correct attitude to the study of the particular processes in the chosen technology.

The technologies which are distinguished by the conversion or transformation of raw materials, can be classified roughly by the source of the raw materials. Thus, cements, ceramics and alkalis are based on inorganic chemistry; and coal and petroleum products are based on organic chemistry. A third class of technologies using plant and animal products for raw materials require biochemistry, in addition to organic chemistry, for their understanding; examples are the manufacture of tobacco, textiles, leather, antibiotics, and finally the largest and most important section in this group, the food processing industries—described generally as food technology. Food technology then is the preservation, storage, conversion, refining and compounding of biological raw materials (*e.g.*, flesh, milk and eggs from animals; and seeds, roots, fruit, juice, leaves, stalks of plants) in a form which is suitable for foods.

*The Food Industries*

For commercial or statistical purposes, products can be classified into industries as given in Table 1. The order of these industries represents their relative value in New Zealand, and it is interesting to note that they have much the same order of importance in the United States of America.

Classification by industries has limited value in the study of food technology, so Table 2 shows a classification based on a similarity of techniques and gives some examples in each class.

TABLE 1: FOOD INDUSTRIES

<i>Industry</i>	<i>Some Examples</i>
Meat	Chilled and frozen meat, bacon, small goods
Dairy	Butter, cheese, liquid milks, dried milks
Other	Fish, food-preparations
Beverages	Brewing, malting, aerated waters
Milling and Baking	Flour, bread, biscuits
Plant products	Canned fruits and vegetables, frozen vegetables
Confectionery	Cocoa, chocolate, sugar goods

Chemists and chemical engineers were able to get a foot-hold first in those food industries where refined products were made by relatively complex processes, *e.g.*, cooking oils, sugars, starches, but in later years, chemists (in quality control, research and development) have been able to make a major contribution in the food preservation industries. Chemical engineers have been employed to a lesser degree in the general food industry, although there is plenty of scope for their efforts.

TABLE 2: FOOD PROCESSING

## PRESERVATION

*With little or no change in form:*

- REFRIGERATION to give chilled fruit, meat, milk
- FREEZING to give frozen meat, fish, vegetables
- PASTEURIZATION of milk, beer
- STERILIZATION of milk, juices
- CANNING of plant products, meat, milk
- CHEMICAL and other preservation

*By moisture removal:*

- SUN DRYING of fruits
- DEHYDRATION of fruits and vegetables
- DEHYDRO-FREEZING of soup ingredients
- FREEZE DRYING of meat, fish, plant products
- DRIED POWDERS such as milk powder

*With change in form:*

- PICKLING using salt and vinegar
- FERMENTATION such as sauerkraut
- SUGAR PRESERVATION as in jams and jellies

## MANUFACTURE

*Refined and derived foods:*

- FLOURS; wheat
- STARCHES; corn, wheat
- SUGARS; sucrose, lactose
- FATS, OILS; butter, olive oil
- FERMENTS; cheese, beer
- PROTEIN DERIVATIVES; skim milk, soya protein
- EXTRACTS; vanilla
- CONDIMENTS; spices

*Compounded and reconstituted foods:*

- |                  |                     |                |
|------------------|---------------------|----------------|
| BAKING           | SAUCES              | AERATED WATERS |
| PRE-MIXES        | CONFECTIONS         | ICE CREAMS     |
| PRE-COOKED FOODS | RECONSTITUTED MILKS | STOCK FOODS    |

### *Biological Raw Materials*

Food is food to microbes as well as to man, so that the controlled use of microbial action is a special branch of chemistry—fermentation chemistry—and is used in brewing, cheesemaking, and breadmaking. Without the ability to control microbial action, the food spoils, and this spoilage of raw materials, most rapid in milk and fish, makes the food industry different from other process industries. From the moment that food is harvested, deterioration must be guarded against, and in this respect the biochemistry of post-harvest changes in meat or plants has been well studied. Every food technologist knows of the deterioration caused by enzyme activity in peas caused by bruising at harvesting, or the effect of enzymes in the milling and baking industries. Hence enzymes, the natural organic catalysts found in all living things, are of special significance to food chemists and are a special branch study of their own.

It should be clear, therefore, that chemists working in the food industry should be fortified with a knowledge of biochemistry and preferably some microbiology. The food technologist, in addition, requires to know the principles of sanitation.

### *Special Branches of Chemistry*

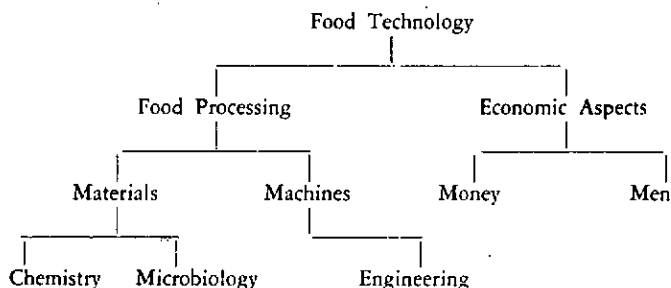
The chemist is not yet released from his duties, because the purchaser of food requires also that his goods be attractive in flavour, in texture and in colour. Furthermore, he or she expects the *same* uniform quality every day in the year. To achieve this end, there is required an understanding of the chemistry of flavour, of texture (tenderness in meat for example), and of colour. A host of chemists throughout the world is working in these special branches of chemistry. Workers in New Zealand are active in many fields of specialized chemistry applied to agriculture, *e.g.*, fat chemistry, dairy chemistry, meat chemistry, wheat chemistry and protein chemistry.

### *The Place of Chemistry*

To control the characteristics of a material, one must have knowledge of the appropriate sciences. In food technology, chemistry is of great importance, important not only in a study of raw material characteristics, but also in conversion characteristics, whether the conversion taking place is due to some unit operation (*e.g.*, heating) or due to microbial action. After manufacture, food is stored in warehouses, shops or homes, but during this time chemical changes can take place, for example, the rancidity of fats, or the browning reaction between sugars and proteins. Thus, in all stages from raw materials through conversion to storage, the chemist is in action.

I have stressed the importance of chemistry in food technology because that is the subject of this paper, but for balance and correct perspective indications are given in Table 3 of the place of chemistry in relation to the other fields of study.

TABLE 3: THE COMPONENTS OF FOOD TECHNOLOGY



From Table 3 it can be seen that the three basic studies are Chemistry, Microbiology and Engineering and these are combined to give a composite discipline called food processing. The creation of a new attitude or discipline is well known to some people in the development of chemical engineering from chemistry and engineering, and food processing is but one extension of this principle.

#### *Bachelor of Food Technology*

The new degrees in food technology in New Zealand follow the plan of Table 3. The basic importance of chemistry is well illustrated by the fact that among the 17 units in the 4-year course there are not only three stages of chemistry, but also further chemistry in sections of the two stages of food processing. One can enter the portals of chemistry through B.FoodTech. as well as through B.Sc. or B.E.(Chem).

#### **FOOD CHEMISTRY**

In this section I wish to deal with chemistry in the food industry more explicitly.

Neglecting the incidental use of chemistry in control of boiler feed water, tin plate lacquers for canisters, etc., there is the progressive application of basic food chemistry as shown in Table 4. The basic chemical groupings (such as fats, proteins, etc.) in the first column are used in the study of the complex raw foods (such as meats, milk, vegetables) and the results are applied to food technology, or to cooking and nutrition which is not under discussion here.

TABLE 4: BASIC AND APPLIED FOOD CHEMISTRY

<i>Basic Food Chemistry</i>	<i>Application to Raw Materials together with biochemical actions (Examples)</i>	<i>Application to Food Technology</i>
Fats, oils and other lipids	Meat, fish, poultry	Evaluation of raw material for marketing, storage, preservation manufacture.
Sugars, starches and other carbohydrates	Milk, eggs	
Proteins	Honey	Requirements for processing and effect of processing on nutrition, colour, etc.
Vitamins		
Flavour and aroma	Fruits, vegetables, seeds, nuts	Requirements for processing on nutrition, colour, etc.
Fermentation	Additives	Effect of storage on taste, texture, etc.
Water and minerals		

NOTE—These groups in the first two columns are fundamental to cooking and use of foods in the home.

#### *Fats, Oils and Other Lipids*

Edible fats are not chemically distinct from edible oils. Physically, oils are liquid at room temperature whereas fats are more or less firm. Usually, oils are derived from plants, and fats are derived from animals. The mineral oils and the volatile essential oils have no nutritive value, thus, in this paper, reference to an oil or a fat implies an edible oil or fat.

Oils and fats belong to a group known as lipids, other members being waxes, phospholipids, and sterols, together with various hormones and pigments. To examine the lipids in a food material they usually are extracted by a solvent such as ethyl ether. The "crude fat" or "ether-soluble fraction" can then be classified by boiling with an alkali such as sodium hydroxide; the various fats, waxes, lipids and free fatty acids form soaps which disperse in the water together with water soluble products, whereas the sterols, hormones and pigments remain behind as the non-saponifiable, non-water soluble fraction (usually only about 1% of the total).

Commercial fats are mixtures of many individual fats, each individual fat usually being a triglyceride formed between a glycerol molecule and three fatty acid molecules. A fatty acid has a hydrocarbon chain with a methyl group at one end and a carboxyl group at the other. In a fat the carboxyl group is linked by ester bonding to the glycerol molecule.

In some fats all the possible hydrogen linkages are filled and the fat is said to be saturated. If there are still unfilled linkages, the fat (or more correctly the fatty acid) is said to be unsaturated. The degree of unsaturation has important effects in nutrition and in physical properties of the fat.

A variety of biological, chemical and physical factors can cause deterioration of fats and oils and the spoiled fats are commonly said to be rancid irrespective of the cause of the spoilage. When fats oxidize, oxygen combines with the unsaturated fatty acids to form peroxides, the peroxides then decompose and give aldehydes, ketones, and acids which have undesirable flavours and odours; in general, there is an oiliness, then "tallowy flavour", then an acrid taste. High temperatures, light and certain metals hasten fat decomposition by chemical processes. Copper is particularly effective, hence copper vessels, pipes and fittings would be avoided where fat decomposition is to be avoided. Lipases are enzymes that cause fat breakdown with an increase in free fatty acids.

A knowledge of the basic chemistry of fats assists in solving problems associated with fatty foods. Thus, a food may develop a "fishy" flavour on storage or during processing, and by judicious use of his basic chemistry, the food technologist can often solve the problem. Of great value to him are the anti-oxidants which greatly retard the oxidation process which causes fat spoilage. Sometimes oxidation problems become very complex. For instance, a problem in stored cheese is that of "tallowiness" or discoloration in which the normal yellow of a cut cheese contains areas of whitish cheese of undesirable flavour. The defect, which can be most serious when cheeses are stored for any length of time, is caused by oxygen from the air seeping through the cracks in the cheese and attacking the fat. The problem is complicated by the types of bacteria present and their demand for oxygen. Although anti-oxidants are a solution or partial solution to many of the problems, their use is severely restricted by the regulations governing the food industry. Preventing oxygen entry to the cheese by wax coatings, plastic films or, alternatively, by minimizing cracks in the cheese by better handling are all helpful measures. It is important to note this example because in food technology, not only must a solution be found, but it must be one acceptable to the manufacturer, the distributor, the consumer and the legislator.

In the processing of fats and oils the crude oil material can be obtained (a) by rendering (heating) of animal tissues, (b) by expressing or extraction from seeds, or (c) by mechanical separation from milk. The oils from (a) and (b) are refined by filtration,

then by alkali reactions to remove free fatty acids and other impurities (note that if alkali reaction is done quickly enough, only a little oil reacts with the alkali and is lost in the soap stock). The oil is bleached by activated carbon, deodorized by steam distillation and chilled to give the correct texture.

When the oils are to be "hardened", a process of hydrogenation is carried out. Here the pure hydrogen gas is reacted with oil at the correct temperature and under the influence of the correct catalyst. Control of the addition of hydrogen to the unsaturated fatty acids is not easy, nevertheless the operation is widely used in the fats industry.

In buttermaking the fat is concentrated by cream separators, the cream then is chilled, the fat partly crystallized, then the phase is inverted by churning, the aqueous portion being removed by simple draining. Further water removal from butter leads to "dry butterfat" and to obtain this product the water is removed by melting and centrifuging or by heating. Pure butterfat is a mixture of fats in which the proportions of individual fats vary with the type of cow, type of feeding, the season, etc.

#### *Other Food Groups*

The chemistry of fats and oils has been outlined to show the subject development. Similarly, the chemistry of carbohydrates could be given, their importance in foods indicated and the technology of sugar and starch production outlined. Or the chemistry of proteins could be indicated, a particularly fascinating facet of chemistry and one of great importance to mankind. Another facet of great importance is fermentation chemistry which is a study of the reactions associated with yeasts, moulds and bacteria used in the manufacture of bread, beer, wine and cheese.

TABLE 5: COMPOSITION OF SOME RAW MATERIALS

<i>Materials</i>	<i>Percentage Composition (average)</i>			
	<i>Water</i>	<i>Protein</i>	<i>Fat</i>	<i>Carbo- hydrates</i>
<b>PLANT PRODUCTS</b>				
Wheat	8.7	11.7	2.0	72.8
Potatoes	77.8	2.0	0.1	19.1
Carrots	88.2	1.2	0.3	9.3
Lettuce	94.8	1.2	0.2	2.9
Apples	84.1	0.3	0.4	14.9
<b>ANIMAL PRODUCTS</b>				
Milk	86.3	3.4	4.7	5.0
Eggs	74.0	12.8	11.5	—
Beef	67.0	19.3	13.0	—
Pork	53.9	15.3	28.9	—
Fowl	55.9	18.0	25.0	—
Cod	82.6	16.5	15.0	0.4

To give some idea of the range in composition in foodstuffs, the proportions of these main groups in some common food materials are shown in Table 5. The table does not include the small quantities of minerals, vitamins, etc. that are also present.

Composition is variable, and therefore is always a trial to the food technologist, so the values given in the table must be taken as average or indicative only.

## THE CHEMIST IN ACTION

### *Raw Material Evaluation*

In a food processing plant the quality control officer is either a chemist (by science training) or a food technologist, and his work is of great importance to the company's progress. He is required to keep a close check on the quality of the raw materials entering the plant and sometimes to grade them for use in the various products manufactured. In many cases payment to the farmer is based on the quality of his farm produce, for instance, the measurement of the amount of butterfat in milk as delivered.

In some cases, mechanical devices are used to give arbitrary (and rapid) assessment of a quality feature, but correlation of the results from the gadget with results obtained chemically must be carried out from time to time. As an example, maturity in peas for canning or freezing can be assessed by chemical determination, but this is too slow for daily production requirements, so a mechanical pendulum device called a tenderometer is used and payment made accordingly.

The question of maturity in relation to final product quality and in relation to day-to-day operations in a food processing plant is of considerable importance and much effort, from fundamental to empirical, is expended to increase our knowledge of post-harvest changes in fruit, vegetables, meat and other products. This is the field of the biochemist, a picked apple being as much a living thing as one on a tree.

Fruit may be taken as an example, and the chemistry of colour, texture and flavour considered. The colour of fruit is due to the fat soluble chlorophyll and carotenoids, and the water soluble anthocyanins. As ripening takes place the green chlorophyll is destroyed and the red-orange carotenoids increase. Other reds and blues are due to anthocyanins, often as pigments which develop during ripening.

The texture of a fruit, *i.e.*, its firmness and juiciness can often be related to the structure of the cell walls and the nature of the cell contents. Thus, a common chemical change of the cell contents is the degradation of pectin during ripening.

The flavour of fruit is greatly influenced by the ratio of sugar to water-soluble acid. While maturing on the tree, the sugar content increases and the acid content is decreased, but after harvest, sugar increases only by conversion of the starch; the acid content decreases slowly. Apart from the taste of sweetness or sourness, we have the characteristic flavours caused by esters of the lower fatty acids and alcohols, free acids and alcohols, and lower aldehydes and ketones. For instance, pineapples contain many esters, principally ethyl acetate; aldehydes are important in tomato flavour; terpene hydrocarbons are important in the flavour of oranges and grapefruit.

### *Processing*

At all stages during processing, the product should be sampled and checked for normality. Where corrections can be applied, there is no great worry, but a significant variation which cannot be corrected immediately is a defect and the problem of tracking down the cause of a defect, and providing a solution, can be long, sometimes tedious and frustrating, but at other times interesting and fascinating. For example, a discoloration of meat surfaces at a meat works was traced to nitrite contamination, the formation of nitrite in turn was traced to microbial activity on the traces of ammonia present in condensed drops on the ceiling. When the drops fell on to the carcasses discoloured areas were formed.

One could give a list of defects which are troublesome in food processing, but it is preferable to classify the problems into groups. One such group is that of protein denaturation which relates to molecular changes in the protein structure so that solubility, dispersion, or water holding capacity of the processed product in water is adversely affected. This problem arises with dried milk, dried egg, meat and fish. It is clear that with the renewed interest in dried products, especially freeze-dried products, this subject is of considerable interest. This grouping is a typical example of the fundamental approach in food chemistry. In this case the study of animal protein has been applied to milk, eggs, meat and fish.

### *Storage*

As mentioned earlier the processed food must be stored, but defects can arise in long term storage. Although pathogenic defects are extremely rare, spoilage defects relating to taste, colour, or texture do arise. Once again, every attempt is made to relate seemingly "different" problems to well known classifications. One example is that of the "browning reaction", in which proteins and sugars can react to give brown pigmented substances. In baked and roasted foods this

reaction is looked upon as a gain, but in storing dried and concentrated foods, the reaction causes a colour and taste defect. To avoid this browning reaction, it is known that food should be dried to a low moisture and not be subjected to high temperatures in processing or storage.

The food industry has been shown to be a technological industry where several disciplines are integrated to the greater advantage of the industry. The chemist and chemical engineer with their sound basic knowledge of chemistry and chemical engineering have contributed and will continue to contribute to advances in the industry, but they are members of a team and their full advantage can only be exploited as active members of that team where they will be the "Chemists in Action".

Perhaps Milton could foresee the problems in Food Technology when he wrote:

*For hot, cold, moist and dry, four champions  
Strive here for Mastery.*

and perhaps Browning saw the answers when he wrote:

*The common problem, yours, mine, everyone's  
Is—not to fancy . . . but—finding first  
What may be, then find how to make it fair  
Up to our means.*

---

## ESPERANTO SCIENTIFIC ASSOCIATION

A New Zealand Esperanto Scientific Association was founded in Wellington last year by a group of Esperantists who are also scientific workers. The President of the Association is Dr W. Harris of the Geological Survey and the Secretary is Mr E. R. Dearnley of the Farm Advisory Division of the Department of Agriculture. The aims of the Association are to encourage the interest of scientists in Esperanto and of Esperantists in science.

The first International congress of Esperantists scientists will be held in Copenhagen in August, 1962, in connection with the 47th Universal Congress of Esperanto. The special theme of the Congress will be the effect of language problems on scientific work. To assist in providing a New Zealand contribution, the Esperanto Scientific Association requests any Institute members with experience in this matter to send a report to Mr Dearnley, who will translate it into Esperanto.

The International Esperanto Scientific Association publishes a review, *Sciencaj Studoj* (*Scientific Studies*), and Mr Dearnley will be pleased to contribute translations of any articles therein for members or to consider articles from Institute members which might be of interest to the international public.

## BOOK REVIEWS

*THE CHEMISTRY OF HETEROCYCLIC COMPOUNDS*, by G. M. Badger, Academic Press, N.Y. and London, 1961. 498 pages. Price, 12.00 dollars.

This book is addressed to advanced and graduate students. One can only hope that students these days are not expected to remember even a fraction of the contents of a work such as this. It fills a real need for a modern fairly comprehensive account of heterocyclics of an advanced textbook nature, and as such provides a general background for those engaged in research in this field.

It ranges from a brief account of the  $\pi$  electron distribution in the various ring-systems, through some reference to physical data, such as u.v. spectra, and key syntheses of the simpler ring-systems, to an account of the chemistry of a good selection of the more important heterocyclic natural products and synthetic drugs.

It has a distinctly Australian flavour (the author is Professor at Adelaide) including some accounts of Australian natural products research, and of synthetic work such as that of Professor Albert. It is particularly up-to-date, including for example, reference to the synthesis of chlorophyll (1960) and the synthesis of reserpine (1958).

References to original literature are liberal. The book provides also a useful guide to recent review articles, to the standard work of Elderfield, to specialized volumes in the "Interscience" series on heterocyclics, and to the several smaller modern works and symposia on more specialized subjects.

The work is presented in a very readable way and has a pleasant informality in nomenclature and presentation. There is a good index and very few errors were seen.

It is one of a series of monographs on Organic and Biological Chemistry—general editors L. F. and M. Fieser.

—E.P.W.

*A HISTORY OF CHEMISTRY*, Vol. 2, by J. R. Partington, Macmillan and Co., London. 795 pages, 38 figs. Price £5 5s. 0d.

This is Volume 2 of a 4-volume work—Volume 1 is still in preparation. This volume traces the development of the chemical aspects of science through a maze of fact and fantasy, with the slow emergence of scientific method, by summarizing the contributions and philosophies of some 200 persons from da Vinci (d. 1519) to Fuchs (d. 1813). However, it is not the full story of these times since Volume 3 (in press) also covers this period. Thus the rise of phlogiston theory through Becker and Stahl is included but not its overthrow. Presumably this falls into the third volume which includes French chemistry. Priestley and Cavendish do not appear in Volume 2.

Each individual is treated systematically with a brief outline of his life and a thorough listing of his relevant publications, including various reprints and editions. The space given to each ranges from a few sentences to 35 pages on Paracelsus and 52 on Boyle. In addition, groups of workers are introduced by general sections such as Iatrochemistry, Poisons, Lapidaries, Phlogiston, etc.

As one can expect from Professor Partington, this is a work of devoted and assiduous scholarship. For the common chemist, however, therein lies its main demerit. The book abounds with quotations in the original languages—Latin, Greek, 16th century French, Dutch, etc. This is the correct way to quote, of course, and admittedly Professor Partington has paraphrased the essential part of most quotations (checks on a few quotations within this reviewer's comprehension indicate that these are excellent concise summaries); but most readers, not being multilingual, would probably prefer to rely on Professor Partington's ability and integrity in translation and so obtain the full significance of the quotations. Even the 16 lines described as "a succinct account in easy Latin of the 3 earths" is likely to daunt most modern chemists.

Let this complaint not deter the reader interested in the swaddling days of science. Apart from fascinating reading there are lessons to be learnt from this account of minds grappling (as their true descendants still do) with the unexplained at the edge of the framework of their age.

—N.T.C.

*ATOMIC-ABSORPTION SPECTROPHOTOMETRY*, by W. T. Elewell and J. A. F. Gidley. Pergamon Press, London, N.Y., 1961. 102 pages. Price, 30s.

Since the publication of Walsh's pioneer paper in 1955, interest in the application of atomic absorption spectra to chemical analysis has been growing at an ever-increasing rate, and the authors of this small volume are to be congratulated on producing the first book devoted wholly to the subject. The book is well produced and printed, the style is clear and misprints are few—the worst occurring on page 33 where the temperature at which potassium is over 80% ionized in a flame is given as 2,000°C instead of 3,000°C.

The first chapter, on theory, follows Walsh's paper closely. The next section deals briefly with equipment and includes useful instructions for making hollow cathode lamps, but most regrettably gives no information regarding the length of life, the stability and the freedom from background radiation that can be expected. There follows a comparison with flame photometry which includes discussions on the use of organic solvents and on various types of interference. In the following chapter, more detailed attention is given to eight points which must be considered when developing an analytical method for a particular element. Most surprisingly no mention is made here of flame composition or the height in the flame at which the absorption is measured. This is unfortunate, as for many elements both the sensitivity and the degree of freedom from interference are dependent on these two factors.

The latter half of the book is devoted to a more detailed account of the determination of ten elements, namely, zinc, lead, magnesium, manganese, iron, calcium, sodium, potassium, copper and cadmium, and for some of these elements hitherto unpublished material from the author's laboratory is given.

Although there are some statements in the book with which the reviewer does not agree, only a few factual errors have been noticed, for example, the power supply described by Box and Walsh (p. 23) supplies

unsmoothed rectified current, not a.c. as stated, while Clinton's burner (p. 36) was designed for air-coal-gas or air-acetylene, not oxy-acetylene. Any attempt to use this burner with the latter mixture will result in an explosion sufficiently devastating to discourage, if not permanently maim, the most ardent enthusiast.

It is inevitable that, in such a rapidly expanding field, any book published at the present time must be, to some extent, outdated when it appears. Although a paper by Gatehouse and Willis which appeared late in 1961 is mentioned (but not fully discussed) the literature coverage is by no means complete to that date. Among others, papers on magnesium by Leithe and Hofer; on strontium and molybdenum by David, and on silver by Rawlings, Amos and Greaves, have not been mentioned.

In spite of these limitations this book will be of undoubted value for providing a simple introduction to the basic principles for anyone beginning work in this new field of analytical chemistry.

—J.E.A.

*THE FERMI SURFACE*, edited by W. A. Harrison and M. B. Webb. J. Wiley and Sons, Inc., 1961. 356 pages. Price, 10 dollars.

This is the proceedings of an international conference held in August 1960 to consider the progress which has been made in recent years in the understanding of the electronic properties of metals and, by clarifying the current views in this field, to define the most important problems in need of immediate attention. Both the theoretical difficulties experienced in defining the Fermi surface and the concept of the quasi-particle and also the information which has been obtained from experimental techniques involving the de Haas-van Alphen effect, the magneto-acoustic, galvanomagnetic and anomalous skin effects as well as cyclotron resonance, optical and transport properties and studies of alloys, receive consideration. The proceedings culminate in two summaries, one of theory and the other of experiment, which set the contributions made in the papers and the discussion in some perspective and survey the possible lines of future development.

Many new concepts and ideas are presented here for the first time but it is particularly interesting to see that the free electron model is back in fashion, even if interpreted with somewhat more sophistication, since all of the Fermi surfaces which have been measured or calculated are recognizably distortions of the free electron surfaces. However, there is evidently no unanimity as to whether the same Fermi surface or quasi-particle can be employed to interpret all of the experimental observations which have been made on any one substance and it is certainly premature to hope yet for any clear answer to the question of the chemist or metallurgist as to the most satisfactory way to think about metals.

—M.T.C.

*INTRODUCTORY CHEMISTRY* (Second Edition), by Otto Nitz; D. Van Nostrand Company Ltd., 1961. 631 pages. Price, £3.

This book is designed to give those students not majoring in chemistry a sound basic knowledge of the subject. It covers a wide field of physical, systematic and organic chemistry and in addition contains chapters dealing with such topics as plastics, protective and decorative coatings, detergents,

petroleum, atomic energy, toxic materials and biochemistry. Of necessity much of the detail on preparations and reactions of compounds is omitted. However the basic essentials are presented clearly and concisely.

The text is well illustrated with photographs and simple clear diagrams and is presented in a most readable fashion. A brief historical introduction is given with each chapter and modern industrial preparations and uses are well described, the latter often being neglected in standard texts.

Although not suitable as a basic text under present New Zealand conditions, it provides excellent background reading for any sixth form or upper fifth form student and merits a place in any school library.

—R.C.M.

*ORGANIC PEROXIDES, Their Formation and Reactions*, by E. G. E. Hawkins. E. and F. Spon Ltd., London, 1961. 434 pp. Price 80s.

Dr Hawkins set out to provide an account of the chemistry of the organic peroxides and has succeeded admirably. This book far outclasses the somewhat limited work by Toblansky and Mesrobian, and may be taken as probably the best modern, authoritative work on the subject. (The reviewer has heard that Dr A. G. Davies, University College, London, has recently written a book on organic peroxides but has unfortunately not yet seen it.) Dr Hawkins is an active research worker in this field and thus has an intimate association with the topic.

The bulk of the book (331 pages) is devoted to an exposition of the preparation and reactions of the hydroperoxides and the peroxides  $R-O-O-R^1$  where R and  $R^1$  may take a wide variety of forms, to include both linear and cyclic peroxides. This section is followed by an account (23 pages) of the analysis, removal, and applications of peroxides, the latter section giving a brief survey of industrial uses. A final chapter on autoxidation (55 pages) completes the book. An adequate but not exhaustive subject index is provided, together with an author index. The book is attractively produced and the type, formulae, and 1751 references cited are clear and pleasantly free of minor errors.

The book appears to provide an excellent compilation of chemical knowledge on organic peroxides although the mechanistic implications are not always fully covered. The arrangement of the subject does—as the author admits—lead to the fragmentation of certain topics. Thus, the base catalysed cleavage of secondary-tertiary peroxides is referred to, *inter alia*, on pp. 201, 211, 214, 223, 236, 246-248, 272-3, 277 and 299 with little overall discussion. The “ $\beta$ -cleavage” of alkoxy radicals  $R_1R_2R_3C-O$  offers a similar case.

In a book of this scope, specialists in other fields will find points to criticize. Thus Windaus' early formulation of ergosterol as a  $C_{27}$  compound (p. 245) has not been corrected and the diterpenes are still drawn “upside down” (pp. 236, 248), contrary to modern practice.

Such minor defects should not, however, be held to detract greatly from such an excellent survey of the chemistry of the organic peroxides and this book can be warmly recommended to all those whose interests lie in this field.

—B.R.D.

*PHYSICAL CHEMISTRY OF MACROMOLECULES*, by Charles Tanford. John Wiley and Sons, Inc., New York, 1961. Price \$18.00.

This is a good book about macromolecules. Since it deals with their physical chemistry, preparative methods are not discussed. A good point about the book is that it treats macromolecules as a whole and the physical chemistry of such systems is treated merely as an extension of the application of existing physical chemical techniques. Each topic is discussed from a general physical chemical viewpoint and then the particular application to macromolecules considered.

A list of chapter headings indicates the scope of the work. Introduction; Molecular structure; Thermodynamics; Light scattering; Transport processes, viscosity; Electrostatic free energy and polyelectrolytes; Multiple equilibria; Macromolecular kinetics.

This last section on macromolecular kinetics is somewhat weaker than the others, possibly because the main interest of the author is proteins and he is less concerned with the kinetics of polymer formation. The author index suggests a somewhat overemphasis on American work.

Where should the chemistry of macromolecules fit into the present courses? In the reviewer's opinion the classical divisions of organic, inorganic and physical chemistry should be retained up to the Honours level. The reason for this is simply that there is a great deal of known knowledge with which a student should be familiar before he specializes. At the post-Honours level where effective research really begins, a splitting off of new sub-units of knowledge may be necessary as well as desirable since much research is on a specialized level. Thus we might envisage a department of macromolecular chemistry taking students from the existing Honours course for two or three years' research and itself offering a one year post-graduate course in macromolecular chemistry. The present book would offer a very useful text for such a course and the physical chemistry level is such that only a student who had already done an Honours Course in physical chemistry would get the full benefit from it.

—T.A.T.

*IODIDE METALS AND METAL IODIDES*, by Robert F. Rolsten. John Wiley & Sons, Inc., New York, 1961. 441 pp. Price \$17.50.

This book, one in the Electrochemical Society Series, is concerned with the "iodide method" of preparing metals and semi-conductors of very high purity. The author's aim is to provide a "reference book to present to the chemist, engineer, or metallurgist (a) the information necessary to design and operate an iodide cell; (b) the details of the preparation and properties of the metal iodides; and (c) the ways in which these various iodide compounds can be used to prepare high-purity elements or alloys". This goal is achieved.

After a brief introduction and historical survey Chapter 3 presents a general background to the method and its use and discusses the unique properties of iodine relevant to its role in the iodide process. Many readers, particularly those seeking technical details, will regret that this chapter is so short. However, this criticism cannot be levelled at the rest of the book. No less than 61 elements which can be purified by the iodide method are discussed under their appropriate periodic main-group or sub-group. After an introduction summarizing the expected chemical behaviour in the group each member is treated separately. Its uses are outlined, the preparation and chemistry of its iodides discussed—sometimes at considerable length—and the process of purification is then reviewed in detail. The final paragraphs assess the expected quality of the product.

Accompanying this discussion of an element are extensive lists of data. For example, under titanium, tables give values for the atomic number, atomic weight, covalent and ionic radii, ionization energies, thermodynamic properties, melting point, density, crystallographic constants and transition temperatures, Young's modulus, neutron cross section and the heat of formation of oxides and chlorides. Similar values are presented for the three iodides and extensive tables and graphs present data on the deposition processes. The text provides still further information on titanium and its iodides.

The last chapters deal briefly with alloys, the preparation of iodide metals by other techniques and the recovery of iodine. Finally pertinent data are collected together again for a valuable theoretical discussion on aspects of the process.

This book will appeal first to those concerned with the preparation of materials, but the emphasis on theory and the extensive bibliography—739 references are listed—will appeal to many other chemists who are interested in the solid state. It is well produced, has numerous diagrams, graphs and tables and a considerable number of photographs.

—T.N.W.

#### JOURNAL OF CATALYSIS

Academic Press have announced the introduction of a new journal for the publication of original research papers in both heterogeneous and homogeneous catalysis. Studies with a direct bearing on the chemistry of surfaces and on the impact of catalysis on engineering will be included. This new publication, carrying the title *Journal of Catalysis*, will be edited by Professors J. H. de Boer, Technological University of Delft, and P. W. Selwood, Northwestern University. The first issue is scheduled for release early in 1962.

#### BOOKS RECEIVED

*MICROBIAL CELL WALLS*, by Milton R. J. Salton. John Wiley & Sons, New York, 1961. 94 pages. Price, 3.50 dollars.

This is the fourth publication in the CIBA Lectures in Microbial Biochemistry series. It covers isolation and general properties of cell walls, chemistry (chiefly amino acids, amino sugars, and the polyol phosphates or teichoic acids), and enzymic degradation and biosynthesis of microbial walls.

*ORGANO-METALLIC COMPOUNDS*, by G. E. Coates. Methuen & Co. Ltd., London. Second Edition, 1960. 366 pages. Price, 45 shillings.

This book deals with "substances containing metal-carbon bonds". This edition is about double the size of the first edition (1956), an indication of the developing interest in this field. Much of the additional material concerns the alkali metals and transition elements, and valency aspects are considered more fully. There are 235 references but a rather scant index. It contains a surprising amount of practical details for a book of this type and is a very readable introduction to the subject.

*QUALITATIVE SHNELLANALYSE DER KATIONEN UND ANIONEN*, nach G. Charlot. (*Rapid Qualitative Analysis of Cations and Anions*, according to G. Charlot). Third Edition, by A. Pflugmacher. Walter de Gruyter & Co., Berlin, 1961. 112 pp.

A brief review of the new methods of rapid qualitative analysis. *SEMICONDUCTOR ABSTRACTS*, Vol. 7, 1959. Prepared by Battelle Memorial Institute. John Wiley and Sons, Inc., New York, 1962. Price \$20.

Earlier volumes in this series were reviewed in the April and August issues last year. The series terminates with this volume, which contains 3,127 abstracts, owing to the high cost of producing the two volumes which would be necessary to accommodate the 6,000 abstracts available for the next issue.

---

### OLYMPIC CONSOLIDATED INDUSTRIES LTD. POSTGRADUATE RESEARCH FELLOWSHIP

The University of Melbourne invites applications by *31 October 1962*, for the Olympic Consolidated Industries Ltd. Post-graduate Research Fellowship for physicochemical investigations of the surface chemistry of organic polymers and particularly problems of adhesion which are of interest to the rubber industry. The scholar will work in the Department of Chemistry and the salary will be in the range £A1,100-£A1,300. Applicants should hold the degree of M.Sc. or B.Sc.(Hon.) in Chemistry and will be permitted to work for a higher degree. Tourist rate passage will be paid for an overseas scholar. Further particulars may be obtained from the Dean of Graduate Studies, University of Melbourne, Parkville, N.2., Victoria, Australia.

---

### TECHNICAL SALES; GEO. W. WILTON & CO. LTD.

Enquiries are invited regarding a position with this Company related to the sale of scientific equipment throughout New Zealand. Following the merger with Messrs. H. B. Selby (Australia) Limited there are excellent prospects for a person with suitable qualifications, the right personality and with a definite interest in demonstrating and selling equipment in the interesting and ever growing field of research and education.

Correspondence will be treated in confidence and enquiries should be addressed to:

I. L. M. Alderson,  
Managing Director,  
Geo. W. Wilton & Co. Ltd.,  
P.O. Box 367,  
Wellington.

# **FIXANAL**

## **GUARANTEED REAGENTS**

**Speed and exact preparation of volumetric solutions save time and money**

★

These chemically pure reagents are supplied in ampoules and bottles, which contain the correct amount of reagent. To obtain the desired normality (1, 5, 10 litres, etc.) it is only necessary to add the correct volume of pure distilled water.

★

The reagents are accurately weighed and an accuracy within the limits of plus or minus 0.2% is guaranteed.

★

Prices are remarkably competitive and a complete range is available.

★

Also handy rolls Indicator Papers in distinctive plastic containers, with colour chart built in, can readily be carried in pocket. Simple refills available in pH 1/11, 1/5, 5/9, 9/13.

★

*N.Z. Representatives:*

**ELLIOTT BECKETT & CO. LTD.,**

**156 Grafton Rd., AUCKLAND.**

**P.O. Box 989**

**REIDEL-DE HAEN A.G. SEELZE-HANNOVER**

## A well aimed blow by PYREX

A machine called the Turret Chain made these: it automatically makes blownware such as flasks, beakers and other types of laboratory ware, to a very high standard of uniformity. It's the only machine of its kind in Europe. Just an example of how PYREX, the first and most important source of borosilicate glassware in this country, use the latest and best processes available. PYREX are always improving their production methods to attain even higher standards of quality. This is one good reason (among many) why everyone who is looking for quality glassware, looks for PYREX.

### Pyrex beakers and flasks



ENGLISH

# PYREX

Regd. Trade Mark



Laboratory

and scientific

glass

are made in all practical sizes and shapes for students, routine or research work.

**Extremely low expansion coefficient**

virtually eliminates breakage from thermal shock allows more robust construction giving greatly increased mechanical strength

**High stability** against attack from water and all acids (except hydrofluoric and glacial phosphoric)

Therefore durable, accurate, economical, dependable, most used.

N.Z. Agents: Messrs. F. O. & H. S. HART,  
20 Victoria Street, Wellington, C.1

# Gallenkamp

## FLAME PHOTOMETER Mk.II



Still faster — More convenient

accurate determinations of  
sodium and potassium

- Accurate readings in 5 sec.
- Sodium 2 ppm full scale
- Potassium 5 ppm full scale
- Tropicalised photocell
- Immediate operation, no warming up
- Operates on town or bottled gas
- Easy servicing and cleaning

### APPLICATIONS

Sodium and potassium determinations in:

Biochemical samples, pharmaceuticals, cosmetics, foods.

Plant and animal tissues.

Fertilisers, soils, water, oils.

Cement, glass, ceramics and many other materials.

### PERFORMANCE

Sodium 2 ppm (0.087 mE/l) for full scale deflection.

Potassium 5 ppm (0.125 mE/l) for full scale deflection.

\*Calcium 20 ppm (0.500 mE/l) for full scale deflection.

Sample uptake rate: 4 ml/min.

Minimum volume for one reading: 0.5 ml (for accurate results, the average of several readings should be taken).

Repeatability: 1%.

\*Using calcium filter FH-545.

Ask for publication 616

# Gallenkamp

SUN STREET · LONDON · ENGLAND

Appointed Agents in New Zealand

**GEO. W. WILTON & CO. LTD.**

83 Shortland Street, Auckland, C.1

156 Willis Street, Wellington

# GEO. W. WILTON & CO. LTD.

156 WILLIS STREET  
WELLINGTON



63 SHORTLAND STREET  
AUCKLAND

*Established 1905*

Representing the leading suppliers of Scientific apparatus, Glassware and laboratory chemicals, including:—

COOKE, TROUGHTON & SIMMS Microscopes,  
Surveying Instrument

DIFCO Culture Media

EDWARDS High Vacuum Equipment

ELECTROTHERMAL Heating Appliances

ELGASTAT Water Deionisers

ENDECOTTS Test Sieves and Sieve Shakers

GALLENKAMP Ovens, Incubators Etc.

JOHNSON MATTHEY, Platinum Apparatus

L. LIGHT & CO. Organic Chemicals

M.S.E. Centrifuges

PYREX Glassware

SCHMIDT Concrete Test Hammers

UNICAM Absorptiometers — Spectrophotometers

WHATMAN Filter Papers



LARGE STOCKS AVAILABLE . . .

PROMPT AND ECONOMICAL INDENT SERVICE.

*You have a  
Laboratory*



WHETHER it's small or large . . . research or industrial . . . whatever the size or type the N.D.A. can be of assistance to you.

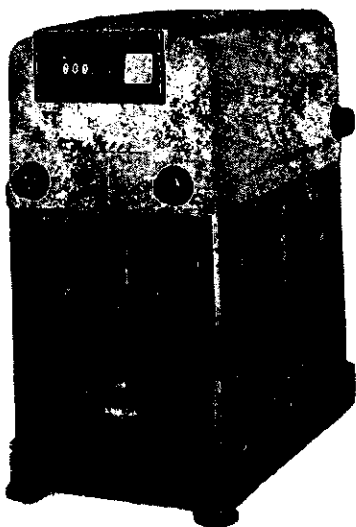
WE stock a comprehensive range of analytical and laboratory reagents, technical and industrial chemicals, scientific apparatus and laboratory equipment.

CONSULT the N.D.A. in regard to your particular requirements. We will be pleased to quote you on an ex-stock or indent basis.

**THE NATIONAL DAIRY  
ASSN. OF N.Z. LIMITED**

THORNDON QUAY,  
WELLINGTON.  
P.O. Box 28.

BEACH ROAD,  
AUCKLAND.  
P.O. Box 1001.



# METTLER MULTI - PURPOSE BALANCE

Capacity 160 gms.

Optical Scale  
1200 mgm.

DELIVERY FROM  
N.Z. STOCK

ASK FOR CATALOGUES ON FULL  
RANGE OF METTLER BALANCES.

★ ANALYTICAL TYPES

B5 B6 M5 H15 H16

★ MULTI PURPOSE H3 H4 H5

★ PRECISION K4 K5 K7 or with  
built-in Taring Device.

K4T K5T K7T

*For all your laboratory requirements*

*CONTACT*

## WATSON VICTOR

**LIMITED**  
(INCORPORATED IN NEW SOUTH WALES)

AUCKLAND

CHRISTCHURCH

WELLINGTON

DUNEDIN

*Established over 70 years*

Registered at the G.P.O., Wellington, as a Magazine.

A. K. WILSON LTD.