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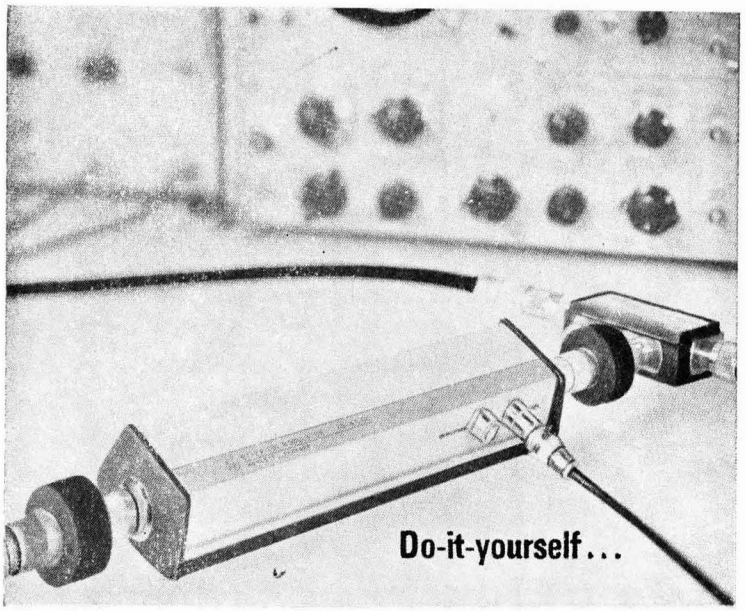

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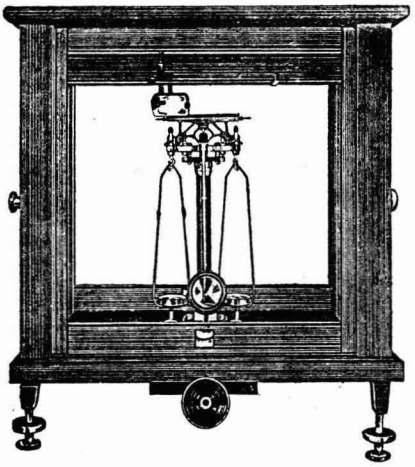

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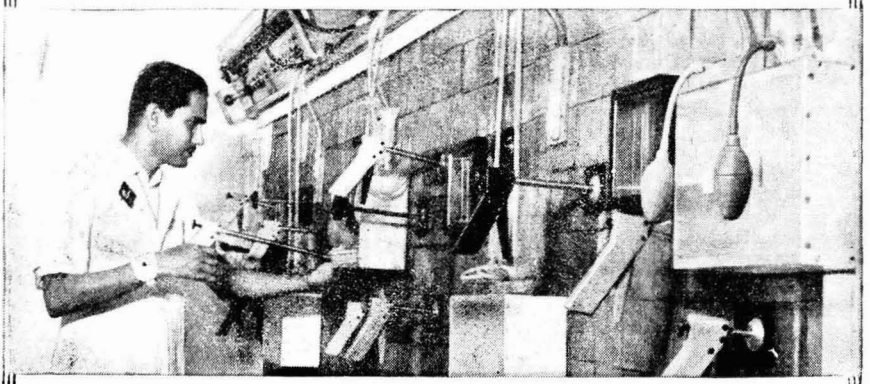

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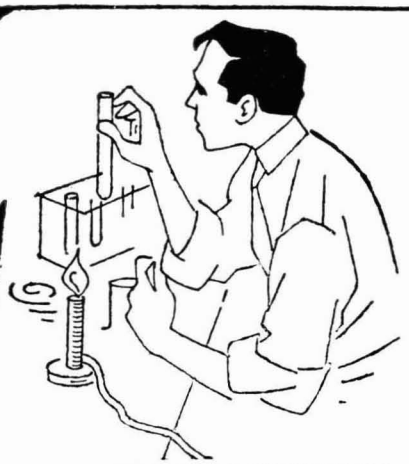

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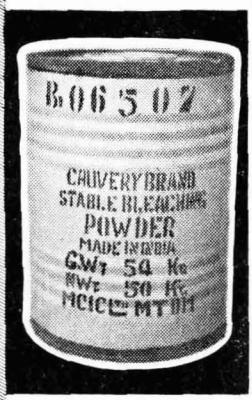

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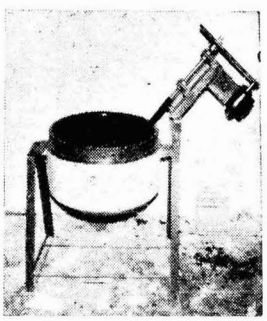

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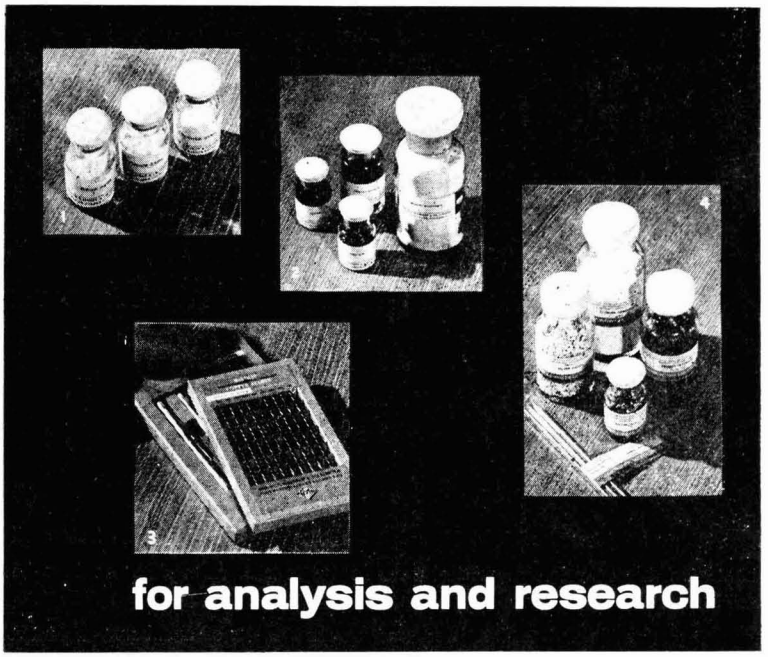

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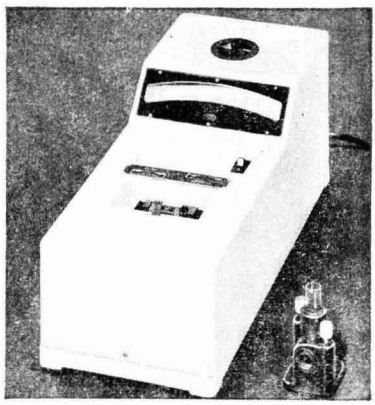

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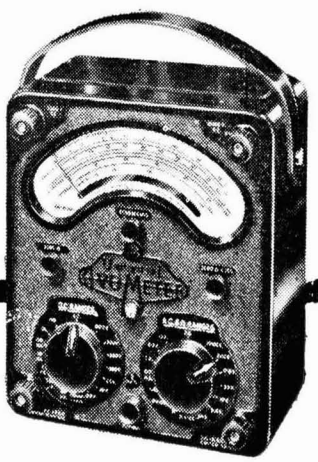

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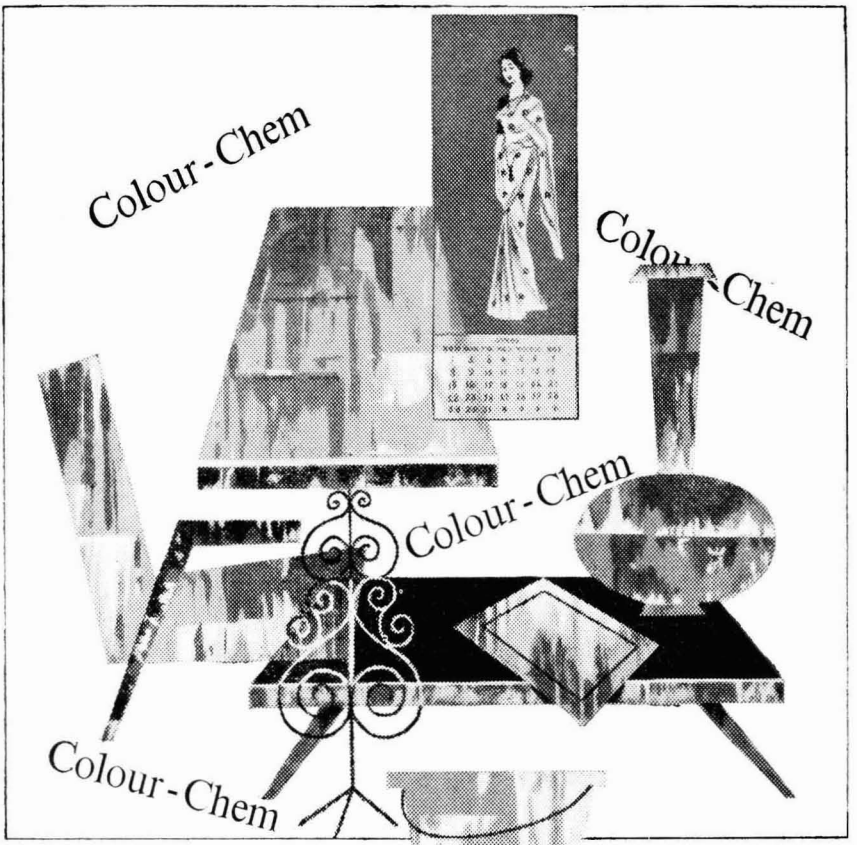

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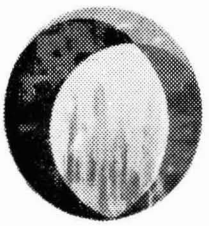

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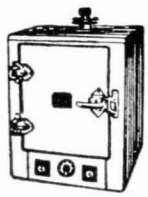
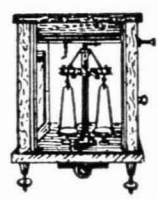
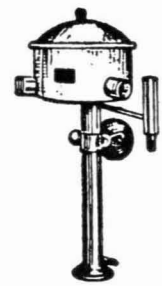

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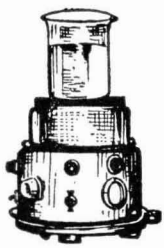
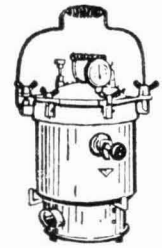
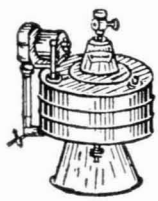
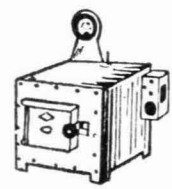
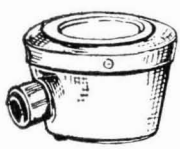

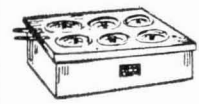

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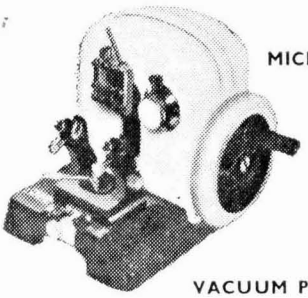

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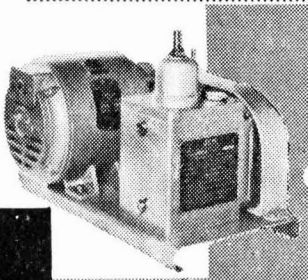

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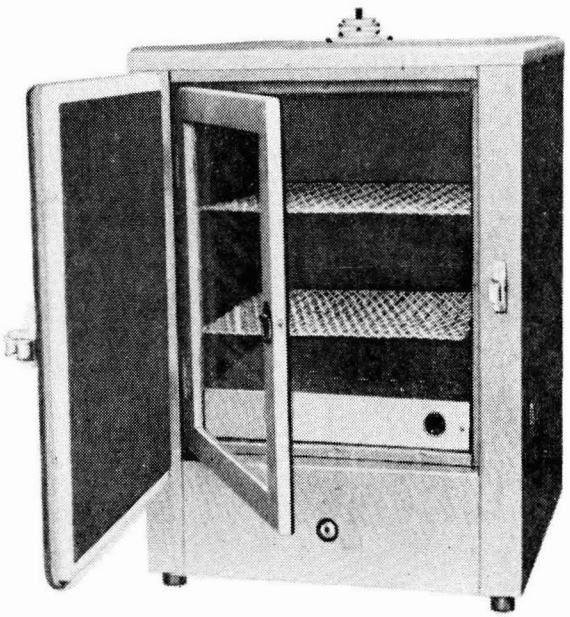

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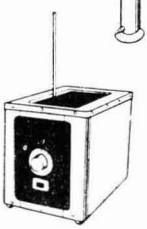

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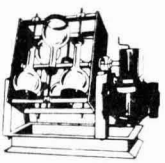

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Current Topics

Utilization of Graduate Engineers

WITH the rapid pace of industrialization, the shortage of technical manpower is being keenly felt in India, and thus an urgent need has arisen for careful planning of our technical education system and full utilization of graduate engineers. Apart from the levels of training required for different jobs, the question of employing the appropriate personnel for the work they can most usefully perform has attracted little attention. This is particularly so in regard to graduate engineers. Prompted by the conflicting opinions on the standard of technical education obtaining in the country and the type of work assigned to qualified engineers in relation to their technical qualifications, the National Register Unit of the Council of Scientific & Industrial Research, New Delhi, conducted a survey which covered 24 industrial establishments in the public and private sectors, employing 251,000 personnel, of whom 6800 are graduate engineers. The findings are quite revealing and should merit the attention of all those concerned with the education, training, deployment and utilization of technical manpower.

The managements of the industrial establishments, to whom a questionnaire was addressed, generally expressed the view that Indian engineers were 'reasonably practical'. One organization felt that the engineers were 'bookish', while two others considered them as 'very practical'.

No indication was forthcoming from the replies to the questionnaire to suggest that technical education in India is particularly deficient. The managements were generally of the view that the universities and colleges produce engineers suitable for their industry, but that fresh graduates need some initial training on the job. One establishment has pointed out that university education cannot be expected to provide engineers specially suited for any particular industry. All the public sector establishments covered by the survey have training programmes, and four out of eight in private sector industries follow such a practice. The period of training varies from a few months to two years in the different establishments.

Managements of seven establishments have welcomed overseas training generally, while four others found it useful in certain fields or for certain specific purposes. Those who favoured it found the overseas trained engineers better capable of taking decisions and giving new ideas. Five organizations did not find overseas training particularly useful. Opinion of senior engineers in one organization was divided on this question.

Ten establishments found postgraduate education useful, while two others found it useful to a limited extent or in specific fields only. One establishment did not find postgraduate education particularly useful. Opinion was divided on this score in another organization. Those who favoured postgraduate education wanted the engineers mostly for planning, design, research and development work.

These opinions of the managements would indicate that university education and training in India are fairly broad-based and of satisfactory standard. However, on-the-job training and some reorientation courses are necessary for the new entrants in a particular industry.

In the opinion of 54 per cent of the engineers covered by the survey, the standard of engineering education in the country is adequate for the job they are handling. According to another 28 per cent, the educational standard is higher than that required for the work they are engaged in. The rest observed that the technical education is inadequate, and this was mostly in respect of practical training which goes with a degree course. They have, however, not indicated what kind of practical training in colleges and universities can do justice to specific requirements of various industries. The consensus appears to be that the technical education provided is satisfactory and in some instances the job handled by the engineers is not commensurate with their educational equipment.

The situation is further spelt out in greater detail in another question regarding the work handled in relation to qualifications. Nearly 60 per cent of the graduate engineers found their education fitting well with their jobs. Another 12 per cent observed that their work could be handled by less experienced graduate engineers. About 20 per cent said that their work could be handled by diploma holders in engineering and another 8 per cent felt that non-engineers could discharge their duties. Thus, about 28 per cent of the graduate engineers felt that their duties could be performed by less qualified personnel, which tallies with the figure of 28 per cent who view that the standard of education is higher than required.

Sixty-three per cent of the engineers find their work 'reasonably creative' and 37 per cent find it 'mostly repetitive'. It would be worth considering whether graduate engineers should continue in repetitive jobs or be replaced by the less qualified engineers in order to liberate them for more creative type of work.

About 35 per cent of the graduate engineers expressed pride in their work, and 45 per cent considered their job as needful duty. These opinions agree fairly well with the answers on job satisfaction, where 40 per cent expressed satisfaction with their work, another 40 per cent were 'more or less

satisfied', while the remaining 20 per cent had no job satisfaction.

Thus, nearly one out of every three graduate engineers is not satisfactorily employed. This can result in frustration, and lowering of productivity and efficiency.

Too Many Scientific Journals?

THE increasing number of scientific journals being published — a recent estimate puts the number over 100,000 — has created serious problems in respect of documentation, storage and retrieval of scientific information. The need for a reappraisal of the situation from a number of angles has been felt and the problems arising out of the enormous increase in the number of scientific journals have to be examined from many basic considerations: Are the present scientific journals serving the needs of the scientific community satisfactorily? Is it really necessary to have such a large number of journals? How are the journals fairing? And what handicaps and problems the journals are confronted with and how they are being overcome?

Two recent reports published by the National Science Foundation, USA (*Characteristics of Scientific Journals*, 1949-59 and *Characteristics of Professional Scientific Journals*, 1962), have revealed interesting facts about 500 American scientific journals that serve an important function by devoting more than half their space to basic research reports [*Science*, **146** (1964), 869]. On an average, these journals publish 1050 pages a year, have 4400 subscribers, and spend annually $ 31,500. The average length of articles published in these journals has decreased substantially and format changes have allowed printing of more words per page. However, despite an increase in advertising revenue and subscription rates, many journals are running at a loss. Journals in engineering, physics and chemistry have most economical formats, and those in biology and social sciences the most expensive. Among the journals published by learned and professional societies, the cost to subscribers is lowest in physics ($ 0.67 a year per 100,000 words) and highest in social sciences ($ 2.98 per 100,000 words). Costs in the case of commercial journals are still higher ($ 3.94 per 100,000 words). The practice of levying page charges against author's institution, initiated by the American Institute of Physics, is now followed by a few more journals, but a majority have not turned to this source of income. It has been suggested that a change to fewer and larger journals would effect some economies.

Studies on subscription patterns and circulation overlaps in respect of the scientific journals are also revealing. Most scientists find it necessary to subscribe to several journals, but it has been found that 500 journals provide fantastically more different combinations than there are scientists. If it is assumed that no individual subscribes for more than 5 journals, then 500 journals provide approximately $2{\cdot}5 \times 10^{11}$ different combinations to satisfy the individual needs of some $2{\cdot}5 \times 10^{5}$ scientists.

In India, the number of scientific and technical journals published during the past 10 years has been increasing at a rapid rate. The number has increased from about 250 in 1955 to over 750 in 1965. It is, therefore, time to take stock of the situation and ascertain whether such rapid proliferation is really necessary and is conducive to maintaining the standards of the journals. As indicated by the National Science Foundation studies, fewer but better journals should meet our needs adequately.

Some Aspects of Cosmic Ray Research*

COSMIC radiation was discovered more than half a century ago by the Austrian physicist Hess who measured the conductivity of air at various altitudes using equipment carried up on balloons. It was already known that the air around us, near the ground, was a conductor of electricity — a poor conductor no doubt, but a conductor nevertheless. Prior to the work of Hess it was assumed that this conductivity was due to radioactive materials present in the earth, which caused ionization in the air close to the ground. Hess showed, however, that the conductivity increased rapidly with increasing altitude and he carried out his measurements up to an altitude of 17,000 ft. Hess's conclusion, in his own words, was: "The only way to interpret these experimental findings was to conclude the existence of a hitherto unknown and very penetrating radiation, coming mainly from above and being most probably of extraterrestrial origin." This extraterrestrial radiation was named 'cosmic radiation' by Millikan in 1925.

Since Hess's discovery, we have gone a long way in our knowledge of cosmic ray physics. We know that cosmic rays are atomic nuclei and electrons which move with great energies in the spaces between the stars of our galaxy; in the regions surrounding the stellar conglomerations of our and other galaxies; and closer to us which move in the interplanetary spaces of our solar system. Cosmic rays and space physics are thus closely linked together, and with the advent of the space age, cosmic ray studies have received a great impetus. Cosmic rays originate in explosive processes in the interior or surface of stars (such as the great flares which occur on the surface of the sun), in the explosions of stars (the so-called supernovae), and in collisions or explosions of galaxies. They are thus part of, and bring us information relating to, these spectacular phenomena in the firmament of cosmic evolution. Cosmic rays receive their energy by interacting with magnetic fields which are imbedded in ionized gas clouds expelled in explosive processes; these magnetic fields and gas clouds are present in interstellar space. The subject of cosmic ray origin, acceleration and propagation is thus largely one of astrophysics, cosmology, magnetohydrodynamics, plasma physics and nuclear physics. Cosmic ray particles cover a very extensive band of energies. The highest energy cosmic ray yet observed had an energy of 10^{20} eV., which is more than a thousand million times the energy of particles accelerated in the world's largest man-made accelerators.

General Aspects of Cosmic Ray Research

The study of the universe around us using the optical region of the electromagnetic spectrum has had a long and distinguished history; most of us are familiar with the great advances in knowledge which have been brought about through investigations in the field of optical astronomy. More recently, over the past three decades of its existence, radio-astronomy, involving the study of radio waves, which lie at wavelengths greater than that of visible light, has in its own right opened up new vistas. Cosmic ray studies enable us to look at the universe through yet another window. What is of great interest about cosmic rays is their particulate character; they are the only form of matter from outside the solar system which we receive directly. Since the cosmic ray particles are electrically charged they are subject to electric and magnetic fields. Finally, cosmic ray particles possess such extremely large energies. The information which cosmic ray studies give us about the universe around is thus quite different and complementary to that obtained via optical and radioastronomy.

The primary nuclei beat against the top of the atmosphere like heavy rain. The earth's surface is protected from this bombardment by the atmosphere. The primary nuclei collide with the air nuclei and cause nuclear disintegrations. Born in these violent nuclear collisions are many types of intriguing short-lived particles. The discoveries in cosmic rays of this rich assortment of particles led to a great upsurge of interest in the field of particle physics; it stimulated the invention and construction of even more powerful particle accelerators and this increased activity promises to lead us to an understanding of the nature of matter much deeper than we have at present. The task of probing into the nature and interactions of these particles is now mainly the province of laboratory high energy physics; but at the higher particle energies as yet unattainable with machines cosmic rays are still a necessary tool.

Cosmic ray research is carried out by space scientists with equipment placed on sounding rockets, satellites and deep space probes, scientists who man ground stations located from the Arctic and the Antarctic to equatorial latitudes, scientists working with detectors flown on balloons over various parts of the globe, scientists working deep underground at depths up to 10,000 ft below ground. It covers scientists whose basic callings are as diverse as astrophysics, geophysics, plasma physics, elementary particle and high energy physics and even radiochemistry. The vitality of cosmic ray physics lies in this immense range of contributions which it makes to the development of science. As a field which has throughout been in the forefront of scientific developments, a field intimately related to so many important branches of research, which utilizes some of the most advanced instrumentation and employs the newest theoretical concepts, and what is important for us in this country, as a field which is relatively inexpensive to work in, cosmic ray research is an area ideally suited for being actively pursued in India.

*A Dissertation by Dr M. G. K. Menon, Senior Professor & Deputy Director (Physics), Tata Institute of Fundamental Research, Bombay, on the occasion of the presentation of the Shanti Swarup Bhatnagar Memorial Award in Physics for 1960 at the National Physical Laboratory, New Delhi, 14 January 1965.

Cosmic Ray Research at the Tata Institute of Fundamental Research

I would now like to take up some facets of the cosmic ray research at the Tata Institute of Fundamental Research, in particular cosmic ray measurements at high altitudes near the geomagnetic equator using balloon techniques and experiments deep underground at the Kolar Gold Fields with particular reference to neutrino physics.

Importance of cosmic ray studies near the geomagnetic equator — The earth possesses a magnetic field which acts as a magnetic analyser for charged particles coming in from outer space. Cosmic rays, right from the lowest energies, are admitted at high latitudes (such as over North America and Europe); but in the equatorial regions only the high energy radiation is allowed to enter. The lower energy region is of particular interest for studies concerning solar-terrestrial relationships, etc.; considerable information on these aspects has become available from extensive investigations conducted at high latitudes, both at ground level and at high altitudes. In contrast, equatorial data have been very meagre. This is because the geomagnetic equator passes mostly through oceanic regions, and the land areas in this belt are rather inaccessible for the most part; few countries advanced in science and technology are located at these latitudes. We, in India, are, therefore, well placed to make important contributions to fill this gap in our knowledge. It may be of interest to point out that Hyderabad (Andhra Pradesh), from where we conduct our major balloon programmes, has a magnetic rigidity of 16·8 GV., which is the highest for any balloon station in the world.

Cosmic ray measurements at high altitudes near the geomagnetic equator using balloon techniques — Cosmic rays are appreciably modified by passage through the earth's atmosphere; for example, we know that heavy atomic nuclei, such as the nuclei of iron, are present in the primary radiation, but since they break up in collisions with the air nuclei they cannot be seen as such at the earth's surface. For direct measurements on the primary radiation it is necessary to make observations well above the earth's atmosphere; for this purpose detector systems are carried to high altitude by balloons, rockets and satellites.

With balloons it is possible to attain altitudes where only a very small fraction, a few parts in a thousand, of the earth's atmosphere lies above the detector system. For most experimental work this is tantamount to being at the top of the atmosphere; at this point the major effort has to go into refining the detector system and reducing the amount of matter in it. There are special experiments for which rockets and satellites are needed; these mostly relate to direct cosmic ray measurements in distant parts of space such as in interplanetary space, in the radiation belts, and so on, or for measurements on the very low energy cosmic rays. There is of course a wide spectrum of activity, other than cosmic ray research, for which rockets and satellites are essential. Even with the great tempo which can be seen in rocket and satellite activity today, more balloons are being sent up and more balloon experiments are being carried out than ever before.

Balloons used for cosmic ray research today are the very large constant volume balloons made out of thin polyethylene sheets. These balloons can ascend to altitudes well over 100,000 ft carrying loads which typically weigh a few hundred kilograms, and remain at these altitudes in level flight for extended periods of time. Such performance is not possible with rubber balloons.

At the Tata Institute of Fundamental Research plastic balloon production was started in March 1956. A major hurdle which had to be overcome was something peculiar to our latitudes. The thin sheets of plastic out of which the balloon is constructed are flexible up to quite low temperatures, around −55°C.; in the case of sheets made from specially selected polymers, this temperature, the so-called brittle point, can be as low as −70°C. Below the brittle point the plastic loses its flexibility and is subject to brittle fracture. At high latitudes the temperatures encountered by the balloon in ascending through the atmosphere are never lower than the brittle point and the balloon remains a flexible object. On the other hand, in the atmosphere over India, and over this latitude belt in general, the lowest temperatures encountered at the top of the troposphere, at altitudes around 50,000-60,000 ft are as low as −80° to −90°C. On our early flights, we have seen our large balloons ascend to these altitudes, and as a result of the loss of fabric flexibility shatter into tiny pieces like a glass thrown on the floor. To overcome this, coloured polyethylene film was used. Carbon black was mixed with the polymer and the extruded film is then of a darkish hue. Balloons made out of this material keep warm by absorbing solar radiation. The exact absorptivity of the film has to be carefully chosen and controlled to get optimum balloon performance in terms of the rate of ascent, ceiling performance, and so on. Tropopause failure due to brittle fracture was completely eliminated by this.

In the United States, for example, balloon flying is not the responsibility of individual groups who wish to carry out work at high altitudes, on the cosmic radiation or otherwise. Contracts are awarded to firms who have specialized in this art. In the absence of such possibilities in India we have had to build up this facility from scratch. The various processes involved are: extrusion of quality controlled coloured polyethylene sheeting with defined specifications, the design and manufacture of balloons, the launching and tracking of balloons and recovery of equipment flown, all of which are handled by the Institute itself. The thin polyethylene film 1·1 mil thick which is used for balloon making is extruded locally in Bombay. A single balloon uses about 60,000 sq. ft of sheet which has to be of uniform quality and free of defects. Level flights at altitudes over 120,000 ft with balloons of volume two million cubic feet have already been achieved.

Balloon flights are now conducted on a systematic basis each year, mainly from Hyderabad, for many types of cosmic ray experiments using both the nuclear emulsion and counter telescope techniques. Some of these experiments are: the fluxes of hydrogen,

helium and heavy nuclei, the charge spectrum of the primary radiation, the isotopic abundances of helium nuclei, the primary electron component, solar neutrons, primary energy spectra and investigations on nuclear interactions at high energies.

It will be seen that an equatorial balloon capability of considerable magnitude has been built up. This is available not only for cosmic ray research but also for other fields such as balloon astronomy and the like. It is thus a facility with wide applications.

Neutrinos: Deep Underground Experiments in Kolar Gold Fields

Neutrinos and antineutrinos are amongst the most elusive of the elementary particles. These particles possess negligible or zero mass and have no charge. They interact through the agency of the so-called 'weak interactions'. To illustrate this point it would suffice to state that a low energy neutrino can pass through the entire earth from end to end with only one chance in ten thousand million that an interaction will take place. Considerable work on neutrinos and their interactions has already been carried out at the great accelerators at Brookhaven and CERN, and on very low energy neutrinos in reactors. There is, however, considerable and distinct interest in studying the 'natural' cosmic ray neutrinos. Firstly, these 'natural' neutrinos have two different origins: (i) there are 'atmospheric' neutrinos which are produced in the earth's atmosphere through the decay of the short-lived pions, kaons and muons; the latter particles result from cosmic ray collisions in the atmosphere; (ii) then there are the 'cosmic' neutrinos which are extraterrestrial in origin. Neutrinos available from the high energy accelerators are at present limited to an energy of about 12 GeV. This will continue to be the case for a decade or more. There are good reasons for the view that a great deal is to be learnt from a study of neutrino interactions at energies higher than this value. Such studies can today be carried out only with cosmic ray produced 'atmospheric' neutrinos which possess energies much higher than 12 GeV.; the actual problem is not one of neutrino energy but of intensity.

Next, there are good scientific grounds to expect that a flux of extraterrestrial neutrinos is incident on the top of the earth's atmosphere. This is one component of the primary cosmic radiation whose existence we know of but which has not as yet been observed. These 'cosmic' neutrinos will provide direct information on conditions in the deep interiors of stellar objects and processes occurring therein. Because of the very nature of the neutrino and the processes in which it is produced, as also its weak interaction with matter, the knowledge which can be acquired by studying it astrophysically will be very different from the knowledge gained through the other components of the primary cosmic radiation, as also from optical, radio and X-ray astronomy. The universe around us, if seen through eyes sensitive to neutrinos, would look quite different from what it appears to us now. Neutrino astronomy will have a bearing on many aspects such as gravitational collapse and supernovae explosions, general relativity and cosmology.

The interest in studying natural neutrinos from the viewpoint of both high energy weak interaction physics and of neutrino astronomy is thus well founded. The problem one is faced with is the actual experimental line of attack. From work carried out over the past few years at the Kolar Gold Fields it has become clear that investigations at great depths underground, at depths of the order of 9000 ft below the earth's surface, using detector arrays of large area, offer many interesting possibilities in the study of 'natural' neutrino physics.

Cosmic radiation, in its penetrating component, the energetic charged muons, can get down to great depths underground and be observed there. One investigation which has always been of interest from the standpoint of cosmic ray phenomenology has been the experimental determination of cosmic ray intensity as a function of depth underground. Earlier work in this direction was confined to depths about 2000 ft underground. In the Kolar Gold Fields, we have in India some of the deepest mines in the world. Members of the cosmic ray group of the Tata Institute of Fundamental Research (S. Miyake, V. S. Narasimham and P. V. Ramana Murthy), utilizing this facility, have measured the intensity of the penetrating component of the cosmic radiation as a function of depth up to 9200 ft below the surface; their measurements relate to depths far greater than in any previous work. From this investigation we know that the intensity of the penetrating component falls rapidly with increasing depth; and the reasons for this are well understood. In fact, the attenuation is so great that at the deepest level of observation, no counts were observed in 180 m^2 days of operation with a solid angle of 3·7 steradians. At such depths the dominant background of charged cosmic rays has been filtered so effectively that the extremely weak signal, that of neutrino interactions, should now be discernible. Large-scale international experiments are now under way, both in the Kolar Gold Fields and in the deep gold mines near Johannesburg (South Africa), to investigate neutrino interactions at great depths underground. The exact physics which will ultimately emerge from these experiments (and others like it) cannot be firmly predicted at this stage; only possibilities and trends can be discerned; after all, these rare phenomena have first to be satisfactorily observed! Such exploratory experiments may in themselves constitute the first attempts at high energy neutrino astronomy; if not, they will at least indicate the feasibility and cost of opening such a window into the universe.

These are only two of the many aspects of the work being carried out by the cosmic ray group at the Tata Institute of Fundamental Research. For the other aspects various papers which have been published can be referred to, such as the Proceedings of the International Conference on Cosmic Rays held at Jaipur in December 1963. The two topics discussed in this dissertation are large-scale programmes involving extensive international collaboration, and it is most appropriate to consider them this year, which is the International Cooperation Year organized at the instance of our late, greatly respected Prime Minister, Jawaharlal Nehru.

Some Investigations on Plant Products*

FROM time immemorial man has made use of plants in the treatment of disease. The pharmacopoeias of many countries of the world include even today a large number of drugs of plant origin. While it is true that purely synthetic compounds are being employed in increasing measure in clinical practice, interest in the examination of plants as potential sources of new drugs has never waned. Whatever be the practical value of plant extractives and isolates, organic chemists have found the plant kingdom to be an inexhaustible storehouse of compounds of extraordinary variety and complexity. To the organic chemist every new molecule of unknown structure poses a challenge and he receives a sense of fulfilment and the thrill of achievement if he is able to arrange the atoms of an unknown molecule in their proper sequence in three dimensions. I should like to present in this dissertation a brief account of the modest efforts in this field of my colleagues and myself working in the laboratories of Presidency College, Madras.

During the course of our work we have had the opportunity of contributing to the solution of the structures of many complex molecules, either wholly or in part. Among these may be listed the alkaloids carpaine, gentianine, tylophorine, tylophorinine, tiliacorine, echitamine, kopsine, venenatine and of compounds like wedelolactone, cedrelone, polyalthic acid, valeranone and veprisone. In this dissertation I should like to restrict myself to a brief description of the methods adopted in solving the structures of just four compounds, wedelolactone, tylophorine, tylophorinine and kopsine, as representative of the approach of organic chemistry in structure elucidation.

Structure of Wedelolactone

The plant *Wedelia calendulaceae* has been employed in Indian medicine for centuries as a corrective for liver disorders. From the leaves of this plant we isolated a crystalline compound called wedelolactone having the molecular formula, $C_{16}H_{10}O_7$. The compound contained one methoxyl and three hydroxyl groups (tri-O-acetate, m.p. 235-7°; tri-O-benzoate, m.p. 267-9°) and had an infrared absorption band at 1707 cm.$^{-1}$, characteristic of an unsaturated δ-lactone. Complete methylation with diazomethane gave tri-O-methyl wedelolactone, $C_{19}H_{16}O_7$. The degradation reactions carried out on this compound are depicted in Chart 1.

Alkaline hydrolysis of the ozonolysis product $C_{19}H_{20}O_8$ yielded a mixture of 6-hydroxyveratraldehyde and 2,4,6-trimethoxybenzoic acid. Working backwards from these products, it is now possible to assign a definite structure for tri-O-methyl wedelolactone itself (Chart 2).

The problem then was to locate the position of the methoxyl group in the parent compound wedelolactone. By the sequence of reactions shown in Chart 3 the structure of wedelolactone could be depicted uniquely.

It is conventional in organic chemistry to regard the structure of a compound as fully proved only if it is synthesized in the laboratory. In view of the finality with which X-ray crystallography can solve the structures of molecules, synthesis is no longer the only method of securing confirmation of a structure arrived at on the basis of

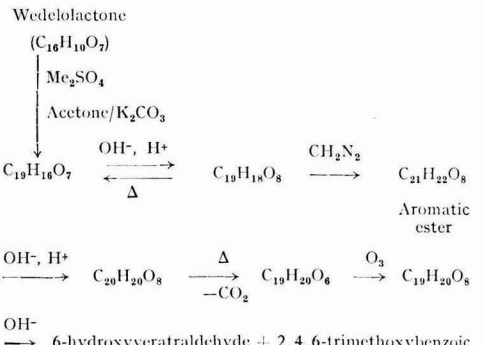


Chart 1 — Degradation reactions of wedelolactone

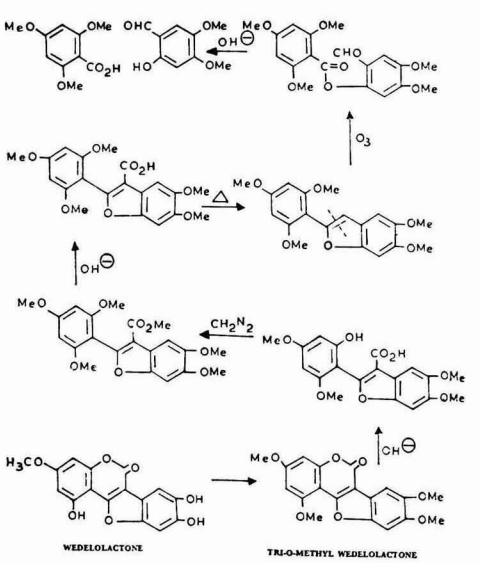


Chart 2 — Structure of tri-O-methyl wedelolactone

*A Dissertation by Dr T. R. Govindachari, Director, CIBA Research Centre, Bombay, on the occasion of the presentation of the Shanti Swarup Bhatnagar Memorial Award in Chemistry for 1960 at the National Physical Laboratory, New Delhi, 14 January 1965.

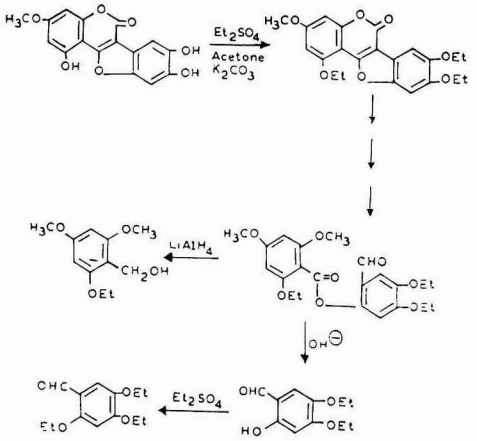


Chart 3 — Reactions leading to the elucidation of the structure of wedelolactone

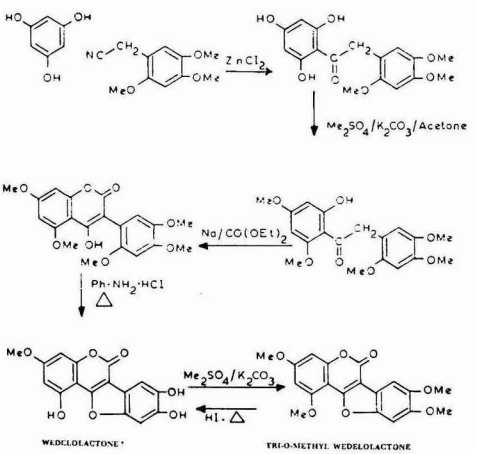


Chart 4 — Synthesis of tri-O-methyl wedelolactone

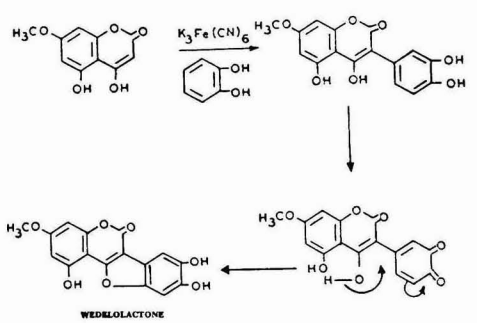


Chart 5 — Synthesis of wedelolactone

degradation experiments. By the steps outlined in Chart 4 it was possible to effect a synthesis of tri-O-methyl wedelolactone identical in every respect with the material obtained from the natural compound.

Recently, a very elegant synthesis of wedelolactone itself has been reported by Wanzlick and coworkers in Germany as shown in Chart 5.

Subsequent to our work on wedelolactone, several other compounds having the same skeletal structure, such as coumestrol, trifoliol, erosnin and psoralidin, have been isolated from plant sources in different laboratories (Chart 6).

Structures of Tylophorine and Tylophorinine

Our work on the alkaloids of *Tylophora asthmatica* gave us much satisfaction in that we were able to disclose a new type of structure not encountered before. *T. asthmatica* is a perennial climber growing widely in the plains of India whose leaves have been used as an efficient substitute for ipecacuanha. Two alkaloids, tylophorine $C_{24}H_{27}O_4N$ and tylophorinine $C_{23}H_{25}O_4N$, have been isolated from this plant. Some of the key reactions leading to the unravelling of the structure of tylophorine are depicted in Chart 7.

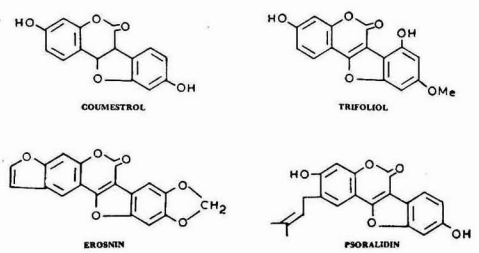


Chart 6 — Naturally occurring analogues of wedelolactone

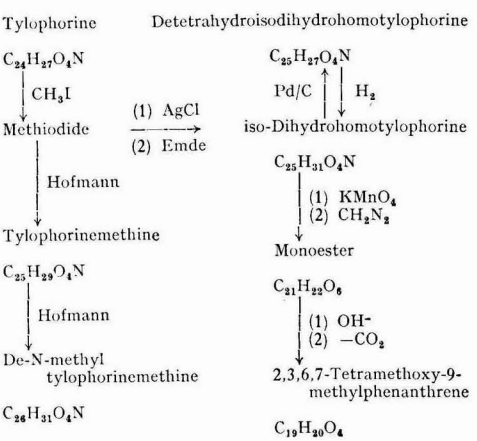
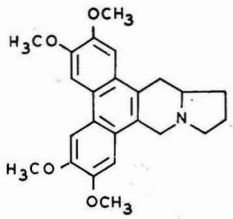


Chart 7 — Degradation reactions of tylophorine

On the basis of these and other experiments tylophorine could be assigned the structure shown below:



TYLOPHORINE

A synthesis of tylophorine was achieved by the sequence of reactions depicted in Chart 8. The racemic compound obtained in the synthesis was resolved through the use of camphorsulphonic acid, the *laevo* form being identical with the natural material in every respect.

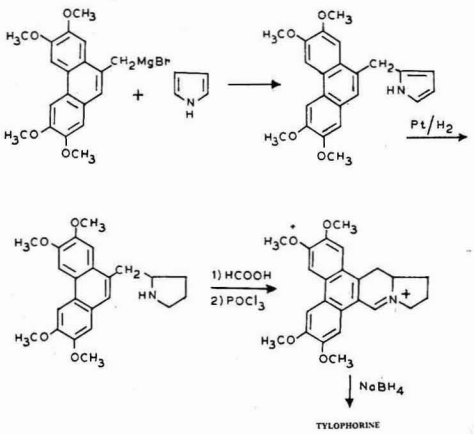


Chart 8 — Synthesis of tylophorine

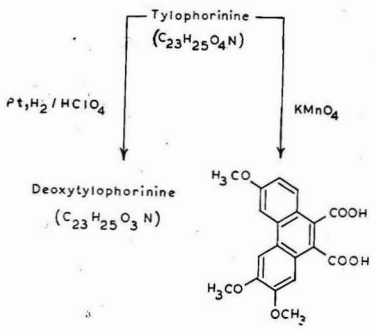
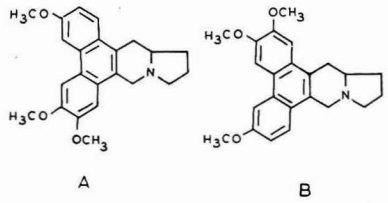


Chart 9 — Degradation reactions of tylophorinine

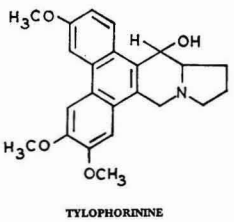
The companion alkaloid tylophorinine had three methoxyl groups and an alcoholic hydroxyl group. Hydrogenation in the presence of perchloric acid yielded deoxytylophorinine, $C_{23}H_{25}O_3N$, proving the hydroxyl group to be benzylic. Oxidation of tylophorinine with potassium permanganate yielded 2,3,6-trimethoxyphenanthrene-9,10-dicarboxylic acid (Chart 9).

On the basis of these results deoxytylophorinine could be assigned one of two structures below:



A B

Compounds corresponding to both these structures were synthesized and deoxytylophorinine was found to be identical with that having structure A. Since the alcoholic hydroxyl group in tylophorinine is benzylic, the alkaloid itself could be formulated as shown below:



TYLOPHORININE

The synthesis of tylophorinine has been recently achieved by the sequence of reactions depicted in Chart 10.

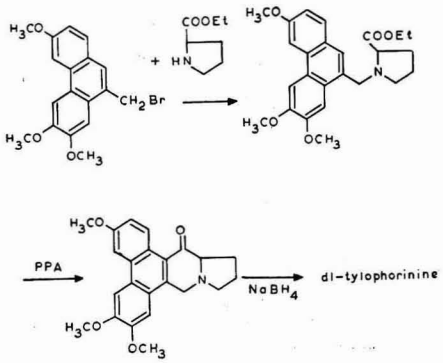
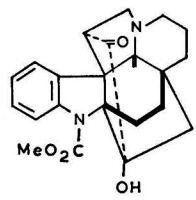


Chart 10 — Synthesis of tylophorinine

Structure of Kopsine

Lastly, I would like to mention briefly our work on the elucidation of structure of the alkaloid kopsine from the plant *Kopsia fruticosa*, carried out in collaboration with Prof. Hans Schmid of Zurich University. Systematic chemical examination of the alkaloids of *K. fruticosa* yielded at least five structurally related alkaloids, of which kopsine was the major one. Kopsine had the molecular formula, $C_{22}H_{24}N_2O_4$. A 5-membered ring ketone, a tertiary hydroxyl and a methyl urethane groups accounted for the oxygen atoms. The ultraviolet chromophore was identified as an N-acyl indoline. The absence of other unsaturation in the molecule indicated a heptacyclic structure for kopsine. NMR data on the alkaloid revealed the environment of the acyl indoline (N_a) moiety and its relation to the hydroxyl group, while those on the lactams derived from kopsine and dihydrokopsines shed light on the neighbourhood of N_b. Hofmann degradation of kopsine gave the methine which was reduced to the dihydro and tetrahydro derivatives. Spectral features and other properties of these compounds helped bridge N_a and N_b and led to formulation of a structure for kopsine.



KOPSINE

The structure of the alkaloid is so complex that classical methods would have been incapable of furnishing a solution in a reasonable time. However, it was possible to arrive at the structure with some degree of assurance in a short time by the extensive use of physical methods like ultraviolet and infrared absorption, nuclear magnetic resonance and mass spectrometry.

Root & Its Environment*

FOR many years plant physiologists have been intimately concerned with the problems of uptake of metals in ionic form by plants from minerals in the soil. It has been known for centuries that soils not only serve to anchor plants through their ramifying root systems but also supply the necessary metals in certain proportions in aqueous solutions. This is a remarkable process as not all metals are needed for plant life. Even among those that are essential some are taken up in large quantities and the regulatory mechanism behind this is a function of the plasma membrane of the living root cell. Genetically speaking, the ability of these membranes to regulate entry of metals varies with the plant species and, indeed, there are many instances of plants accumulating rare metals in sizeable quantities. The precise physiological functions of membranes in relation to movement of solutes is a vast field, and I need hardly apologize for not covering that here.

Against the classical concept of movement of solutes through the root plasma membrane motivated by the pull from the leaves, depending on the plant's water requirements, a new concept has emerged in recent years. This is based on the fact that the movement of water and solutes is not unidirectional. Indeed, some substances seem to move in the opposite direction down the plant stems into and out of the roots. It is true that there were circumstantial evidences in the past for this second phenomenon. But what seems fascinating in this context is the observation early this century by the German scientist Hiltner that the microbial population was many times greater in soils intimately surrounding roots than in soils away from the roots. However, this remained just a postulate largely because techniques of detection of substances that increase microbial fecundity were not precise enough. But today many new techniques for analysing extremely small quantities of substances synthesized by plants have been perfected. These new powerful analytical tools have established beyond doubt that many amino acids, organic acids, sugars and vitamins as well as large molecular substances are released from many plants through their root systems into the adjoining soil zones[1,2].

Soil-borne Pathogenic Microorganisms and Plant Diseases

Looking through the history of the human race, instances are not wanting of the desire in conquerors and explorers like Alexander the Great, Vasco da Gama and Columbus not only to introduce new plants and plant propagules in the new lands they visited but also to take away with them as trophies seeds and

*A Dissertation by Prof. T. S. Sadasivan, Director, University Botany Laboratory, Madras, on the occasion of the presentation of the Shanti Swarup Bhatnagar Memorial Award in Biology for 1960 at the National Physical Laboratory, New Delhi, 14 January 1965.

horticultural materials back to their homelands and plant them in virgin soils ! Little did they realize then that these indiscriminate movements brought in their trail many problems of soil-borne diseases of plants. There is no doubt that we have to face this legacy of the past, and modern quarantine regulations can only take care of the future, but can do little to straighten the past. It is clear, therefore, that such introduction into soils of parasitic microorganisms in the past together with air-borne pathogenic forms that migrate from continent to continent have created agronomical problems in soils in many lands. In fact, the perennation of pathogenic forms in soils has been a complex problem. This is so, because, unlike human and animal disease-causing agents, plant pathogens can be both non-specific and extremely specialized. Those plants that suffer from a chronic debilitating disease keep the pathogens alive longer than those that suffer an acute disease and thereby exterminate themselves and the pathogen. To this must be added the other category of plant diseases where pathogenic forms are capable of surviving in plant remains over long periods until their host of choice reappears.

The precise and conventional way of dealing with the perennial problem of combating disease spread and control has so far been shared by geneticists by breeding resistant varieties and by agrochemists by developing chemical plant protectants. To this, it looks to me, we have to add a new field of research dealing with a possible biological method of control. Work at Madras and elsewhere, particularly in Canada, the United Kingdom and Australia has shown beyond doubt that there is a dynamic relationship between antagonistic soil microorganisms and pathogenic forms in the region of the root. On the one hand, genetic varieties of crop plants bred for resistance exude through the roots metabolic depressants that inhibit germination of spores of pathogens. On the other hand, we have examples of metabolic stimulants exuding from the roots of resistant plants which favour the growth of microorganisms that are antagonistic to the pathogens. It is clear that we have in these two examples the possible key to a gene-controlled mechanism, where the pattern of root exudates, which is a phenotypic expression of a genotype, decides the microbial environment of the roots. There is more than circumstantial evidence that the microbial environment of a genotype in the root region can be altered by spraying on to the leaves energy substances which are readily absorbed, transported and utilized in plant metabolism. The pattern of the microflora of the roots of such treated plants has been shown to be effectively changed[3]. This work done by us at Madras a few years ago has a good future and, indeed, seems to have opened up a vast and fruitful field of research. I say this because in modern agricultural practices there has been a great deal of rethinking on replacement of the age-old traditional method of applying artificial fertilizers to the soil by the newer methods of foliar sprays. As a matter of fact, this technique of spraying leaves of plants with mineral solutions for diagnosing nutritional deficiency has been used for many years by plant physiologists. Horticulturists have been spraying plants with growth substances for spectacular growth effects. Vegetative propagules like cuttings have been dipped in synthetic hormone solutions and excited to root. It was not realized until recently that all these cultural operations in the armoury of agriculturists could have repercussions on the microbial environment of roots. It is becoming increasingly clear, therefore, that the boundaries between plant genetics, physiology, microbiology and plant pathology are disappearing giving way to a healthy integration of these many facets in the study of disease resistance in plants.

We have also been examining at Madras in recent years the problem of seedling infection of rice by a soil-borne pathogenic fungus. Encouraging results have been obtained indicating that an array of energy substances consisting of amino acids and sugars exude out of the roots of germinating seedlings of rice varieties susceptible to the pathogen[4]. These vast quantities of nutrilites are exuded rather dramatically in the first 24 hr of germination followed by a gradual reduction and eventual tapering off by about 80-90 hr. This is a fascinating field for further research and if one were to predict the outcome of such investigations it would probably turn out that the phenomenon is a fairly universal one in many seeds of known genetic origin and is perhaps the cause of seedling mortality which is so common throughout the world.

Root Nodule Microorganisms and Virus Infection

Coming to practical agriculture, India leads in having many varieties of legumes that give the much needed protein for her population. We have here an immense problem of symbiosis between a group of soil bacteria called the rhizobia and the roots of leguminous plants resulting in the formation of nodules which fix elemental nitrogen. A recent chance observation by one of our group in Madras led to the finding that there was a suppression of nodulation in the field bean consequent upon infection by a virus[5]. It is well known, on the one hand, that legumes have a poor protein turnover which is remedied by inoculating their roots with nodule bacteria which share the responsibility of the protein build-up. On the other hand, virus infection of plants has been shown to bring about nitrogen stress at cellular and subcellular levels. In this interesting interaction the virus seems to have the upper hand and does not permit the nodule bacteria to establish itself. It, therefore, remains for future research to explore this peculiar mechanism, but judging from facts so far known about the importance of root exudations on establishment of symbiosis between microbes and plant roots, the lack of incentive for the nodule bacteria to establish themselves in the roots would seem to rest on the paucity of energy substrates in root exudations of the host whose metabolism is crippled by virus infection. Alternatively, such a plant may exude inhibitors inimical to the growth of the nodule bacteria.

Notwithstanding all that has been said, the basic question still remains as to how and why these exudation patterns vary from one genotype to another. It is becoming increasingly apparent that alongside ionic uptake by plants the permeability of

root membranes permits absorption of substances of high molecular weight which are larger than the inorganic ions. There is evidence that products of microbial metabolism from soils can enter the roots with great facility. Quite obviously, in the natural soil environment with a microbial flora constantly competing with the roots of the higher plants for not only ionic material but also for organic substances, many metabolic products of microbial and microfaunal origin would be constantly formed and absorbed by plants. As a matter of fact, many antibiotics are known to be formed continuously in natural soils and all controversy about the stability of such antibiotics formed *in situ* has now been laid to rest after critical experimentation. Currently, we can regard this phenomenon of the generation of antibiotic and other substances like toxins in soils as a normal process proceeding in nature wherever microbes have the necessary energy substrates. It is, therefore, hard to imagine, unless plants are grown under aseptic conditions, that this constant interaction between microbes and roots of higher plants would not be a continuous process. Indeed, this new perspective of the biochemistry of different genetic varieties of plants and their roots grown under natural soil environment and controlled aseptic conditions is to re-examine many intricate problems of plant metabolism and the so-called defence reactions in the resistant varieties. Specific substances broadly termed phytoalexins have been isolated from resistant plants and characterized and these are considered to be a link in the chain of *in vivo* defence reactions in plants. Whilst the formation of specific antibodies during immunization processes in the animal and human systems is well known, such a defence mechanism operating in plant tissues awaits experimental evidence. Nevertheless, *in vivo* processes somewhat akin to antibody formation have been demonstrated in isolated instances. To what extent products of microbial metabolism produced in the soil external to the roots and absorbed into plant tissues through roots would excite the formation of phytoalexins is a burning question and would before long lend itself to resolution.

I have endeavoured to cover some problems of complexity of the microbial environment of roots. To many, plant roots have no more meaning than mechanical props of herbs, shrubs and trees, but to the specialist they have an absorbing interest. Indian science, I feel, has taken note of this vast treasure-house of knowledge that resides underground and I look forward with optimism to the study of the many facets of this problem of ' root-microbe inter-relationships '.

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The Role of Chemical Engineering in India's Atomic Energy Programme*

WHILE the Shanti Swarup Bhatnagar Memorial Award in Engineering has its own value to the individual as a recognition of his personal contribution, its greater implication lies in the fact that it honours the profession of engineers and the high place it gives to original endeavours in the field of engineering sciences. In this age of science and technology, where rapid and revolutionary developments are taking place around us, we cannot afford to stand still, if we are to survive as a nation. We have to master the most intricate and sophisticated techniques and make the best use of our scientific and engineering skills. In particular, in the field of atomic energy, involving as it does a completely new and complex technology, we have the most exciting challenge, a challenge which is being met with remarkable success by our scientists and engineers.

It is symptomatic of the trend of developments in the field of pure and applied science and technology in the country that the first recipients of this award should have been pure scientists and that it should now be the turn of applied scientists to receive this award. Whereas fundamental research in the pure sciences can be judged only by world standards, wherein any contribution is considered worth while only if it adds, even in a small way, to the sum total of human knowledge, the same criterion cannot be applied in the fields of applied research and technology. It is one thing to be fully aware of all the details of, say, a chemical process which may have been fully developed elsewhere; it is quite another thing, however, to set up an industry or a plant based on such a process. It may become necessary to modify the process in such a manner that it can be used with locally available raw materials and in environmental conditions that may be different. A task of this nature is complicated enough in a country which is highly industrialized and in which the various basic processes, technologies and technical know-how are readily available. In a country like India, where such basic industrial and technological know-how is rare, the task of exploiting any new process or setting up any new plant is rendered even more difficult. In such a modern and novel field as nuclear technology where the use of ultra-sophisticated materials and methods is the order of the day, the task of setting up any new process or plant entails an effort of staggering magnitude.

I shall try to trace briefly the various steps that go to transform a newly discovered process into an industrial and technological reality. Any such process starts off with laboratory scale experiments in which all operations are conducted at milligram levels and where attempts are made to modify the basic processes to suit such local variations as there may be in respect of raw materials or environmental conditions. Once such an experiment proves fruitful one goes on to the next scale of operation where a pilot plant is designed, fabricated and commissioned and all operational problems thoroughly investigated. This phase involves kilograms of materials and unless it is successfully followed by a full-scale operational phase, the whole process hibernates purely as a laboratory curiosity. The final phase consists in setting up and operating a full-scale facility which will ultimately deliver the goods. As I have emphasized earlier, we in the Atomic Energy Establishment at Trombay have had to stand on our own feet in respect of all the problems we have been called upon to face in the laboratory scale, pilot plant scale and full-scale operations in respect of almost all the processes required for nuclear purposes. The normal tendency in the country, when facing such problems, is to go in for foreign collaboration, so that one could leap-frog all the teething troubles and go in for a turn-key job where the whole facility is fully operational before it is handed over by the foreign collaborators or experts to the Indian organization. We have always felt strongly that we can consider Indian science and technology to have come of age only when we can design and construct our own facilities, such as chemical plants, engineering works and other facilities, however sophisticated and advanced such designs may be.

I am suggesting this procedure only as a rule, for even in the Atomic Energy Establishment we have had exceptions. There are always circumstances in which collaboration with foreign experts and consortia can be of advantage. The Canada-India Reactor, the Tarapur Atomic Power Project and, to a more limited extent, the Rajasthan Atomic Power Project are instances in point.

It would be useful to mention here some of the special difficulties we have been called upon to face in the design, fabrication and operation of a number of chemical processing plants. India's atomic power programme will consist of three main phases. In the first phase, natural uranium will be used as a reactor fuel. The plutonium thus produced will be used as fuel for the next phase in which thorium will be irradiated to produce uranium-233 which in turn will be used as the fuel for the third phase in which breeder reactors will be employed (the breeder reactors will produce more U-233 than they will consume). Thus, thorium will constitute the basic source material for our future nuclear power programme. India is indeed fortunate in having enormous reserves of thorium in the form of the monazite sands which occur in Bihar and South India. In fact, Indian monazite has a thorium content of about 8-9 per cent which is about the highest in the world. It also contains 0·2-0·3 per cent of uranium, which in view of the size of the monazite deposits, constitutes a far from negligible source of uranium. It was a realization of these potentialities

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that led us to set up a thorium plant as early as 1953. This plant went into operation during the middle of 1955. It was followed by a plant for the production of nuclear grade uranium which was completed in late 1958. In fact, the first ingot of uranium metal was produced in this plant on 30 January 1959. This was followed by the plutonium plant which went into operation in March 1964. It is significant that the process know-how was worked out by Indian scientists and engineers and all these three plants were entirely designed and constructed by Indian scientists and engineers without foreign collaboration.

The thorium plant receives thorium cake, a crude thorium concentrate obtained from the monazite plant of Indian Rare Earths Ltd, a public sector undertaking at Alwaye in Kerala State. This thorium concentrate is dissolved in excess hydrochloric acid and filtered in order to remove solid impurities. Most of the thorium in the filtrate is recovered as sulphate by the addition of sulphuric acid under carefully controlled conditions of temperature and concentration. The thorium sulphate is recovered by centrifuging and it is further purified by re-precipitation. The purified sulphate is converted into a hydroxide and after being washed free of all water-soluble impurities is dissolved in pure nitric acid to yield a solution of thorium nitrate. This solution is concentrated in glass-lined evaporators and cast in trays for solidification. This thorium nitrate constitutes the main end product of this plant. However, an extremely important byproduct is uranium fluoride which is sent for further purification and conversion into uranium metal at the uranium metal plant. The fabrication of the thorium plant in 1954 provided us with invaluable experience which rendered the design and fabrication of subsequent plants for uranium and plutonium relatively less difficult.

The decision to set up a plant for producing nuclear pure uranium metal was taken towards the end of 1956, and the first ingot of uranium metal was produced in January 1959. The first step in this plant consists in the purification of the crude uranium fluoride which is used as a starting material and the production of a nuclear pure compound usually in the form of uranium nitrate. The term 'nuclear pure' has a very special connotation; the specification in respect of purity of any material to be used in nuclear reactors is extremely stringent. For example, the upper limits of certain impurities that can be tolerated in nuclear pure uranium are (in p.p.p. of uranium): gadolinium, $<0{\cdot}05$; boron, $<0{\cdot}1$; samarium, $<0{\cdot}1$; cadmium, $<0{\cdot}1$; iron, <150; and silicon, <40. These figures provide an indication of the complexity of the processes that have to be developed and employed for the production of nuclear pure materials. The very first phase of our uranium plant presented us with a problem of major dimensions. The starting material for a uranium plant is normally either magnesium, sodium or ammonium uranate or an oxide of uranium containing approximately 60-70 per cent uranium, whereas in our case the starting material was a crude uranium fluoride obtained from the thorium plant. It was, therefore, essential to eliminate the fluoride from the salt in the first step and obtain a fairly high grade uranate to carry out subsequent operations. This uranate is converted into uranyl nitrate by dissolution in nitric acid. The nitrate is purified using tributyl phosphate diluted with purified kerosene as solvent. The pure solution of uranyl nitrate thus obtained is treated to produce a uranium oxide with stringent physical and chemical properties. The oxide is treated with hydrofluoric acid gas at about 500°C. to convert it into uranium tetrafluoride. The uranium tetrafluoride is then mixed with granules of calcium metal and the mixture ignited in a remotely operated ignition device, to produce nuclear pure uranium ingots. The purity of uranium is of great significance and hence a strict check has to be maintained on the purity of products at all stages of the process. This is done in a well-equipped laboratory attached to the plant. The present uranium plant is designed to produce about 30 tonnes of nuclear pure metal per annum. With certain additions and modifications its capacity can be increased considerably enough to fuel about 600 MW of nuclear power.

Once the thorium and uranium plants had been completed and the Canada-India Reactor was in operation, the need arose for treating used fuel elements from the reactor and extracting plutonium from them which will form the bridge to the use of thorium for the generation of nuclear power. A plutonium plant is one of the most sophisticated and advanced types of chemical plants and has several unusual features. The difficulty in the construction and operation of such a plant can be gauged from the fact that besides Norway, India is the only country outside the so-called 'Nuclear Club' which has an operating plant. The fuel to be treated in this plant is highly radioactive, with an activity equivalent to that of millions of grams of radium. Hence, all operations right from the moment the fuel element is moved from a lead flask into the dissolver to the stage at which the purified plutonium and residual uranium are separated are remotely controlled. These operations are conducted in cells which have walls made of 5 ft thick high density concrete and which are lined with stainless steel for purposes of containing any leaks which may develop due to an accident. The operations are remotely controlled and monitored pneumatically from an operating gallery. In the final stage when the pure plutonium emerges, the operations have to be controlled to prevent another form of danger — accidental criticality. Plutonium is a fissionable material and if a quantity of this material which is in excess of a specified quantity is accumulated at any place it would result in a chain reaction leading to a nuclear excursion which in turn would result in the emission of large amounts of harmful radiations and the release of highly toxic radioactive fission products. The plant has, therefore, been so designed and the geometry of its pipes and vessels so adjusted that under no conditions will there be any accidental accumulation of plutonium in excess of the critical amounts. As plutonium is an extremely toxic substance, great attention has to be paid to problems of the safety of those operating the plant and those in the immediate vicinity of the plant. In view of

the obvious strategic importance of plutonium in today's nuclear power politics, the technological know-how for the fabrication and operation of a plutonium plant is even less available than that for other plants. The successful completion of this plant is, therefore, an important landmark in the development of atomic energy in India. One more feature of this plant is its low cost. That we have been able to set up such an efficient and technically sound plant at the modest total expenditure of 36 million rupees has evoked highly favourable comments from the numerous experts who have visited the plant.

To provide the uranium required to feed the first stage of our nuclear power stations, a 1000-tonne per day uranium mill is under construction at Jaduguda in Bihar. When a decision was taken by the government to construct this mill, the ore reserves were expected to last about twelve years at the mill's rated capacity. However, recent explorations in this area indicate, the reserves are sufficient to feed the mill for several decades and more ore bodies are being discovered in the immediate vicinity of the mill. In this case also the entire process has been worked out by our engineers and scientists and the mill which is expected to go into operation next year has been designed and built entirely by Indians. An Indian firm of consulting engineers has been associated with the project and they have been given the responsibility for detailed engineering and construction.

Our experience at Trombay shows beyond any measure of doubt that India possesses the necessary scientific and engineering talent to ensure our emergence as an industrially advanced country.

International Conference on Interference & Coherence

D. SEN

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THE International Conference on Interference and Coherence, sponsored by the International Commission for Optics, the Australian Academy of Sciences, the Commonwealth Scientific & Industrial Research Organization and the Australian Institute of Physics, was held from 24 to 28 August 1964 at the University of Sydney. Prof. T. M. Cherry, President, the Australian Academy of Sciences, was the Chairman of the Conference Committee and Dr W. H. Steel, the Secretary. The conference was attended by about 100 representatives from 13 countries, including two from India. A large number of leading scientists in the field, specially from France, took part in the conference. Prof. Cherry inaugurated the conference with an address of welcome which was replied by Prof. A. Marachal, President of the International Commission for Optics. The success of the conference should be attributed to the effort and enthusiasm of Dr Steel and his colleagues of the National Standards Laboratory, Sydney.

The conference was mainly devoted to recent applications of the optical interference and coherence phenomena. There were 25 papers, the presentation and discussion of which took two days. The other three days were devoted to visits to the National Standards Laboratory, Sydney, the stellar and radio interferometers at Narrabri and the Australian National Observatory and Academy of Sciences in Canberra.

The conference sessions were not strictly divided according to the subject of discussion. However, the papers presented can be grouped under the following broad heads: (1) Coherence properties of laser radiation, (2) Applications of the coherence phenomenon to stellar interferometry and optical imaging, (3) Interferometry in radioastronomy, (4) Interferometry in metrology, and (5) New interferometric techniques. A brief review of the papers presented in each of these subjects is given below.

Coherence Properties of Laser Radiation

The scientific session of the conference opened with a discussion on the difference between the statistical properties of laser and thermal radiations, and a critical review of the different viewpoints on the statistics of laser radiation. Prof. E. Wolf pointed out the inadequacy of the classical coherence theory which takes into account the mutual coherence between only two points, for the description of the laser radiation. He presented a higher order coherence theory and described photoelectric photon coincidence experiments for the measurement of higher order coherence functions. Another very interesting experiment described was the detection of the transient interference effect between two non-coherent light sources, obtained from a laser beam whose coherence property has been destroyed by means of a moving diffuser. The highly degenerate nature of the laser beam makes such experiments practicable. The laser radiation contains up to 1000 photons per quantum level as compared to much less than one photon per level in ordinary thermal radiation. The classical analogue of the quantum mechanical two-level laser problem and the different ways in which the Maxwell's equations predict stimulated emission were also discussed.

Applications of Coherence Phenomenon

The intensity interferometer for stellar diameter measurement was an interesting topic discussed at this session. In this interferometer the correlation between the fluctuations of the radiation received at two photoelectric detectors is measured. The correlation is proportional to the square of the fringe visibility in Michelson stellar interferometer. The advantage of the intensity interferometer is that the path difference between the detectors and the correlator needs to be small compared to the electrical bandwidth of the system but not to the optical bandwidth. Therefore, there is no difficult requirement for mechanical precision and a very large instrument with high resolving power can be built and also the effect of atmospheric scintillations is small. A detailed description was given of the intensity interferometer at Narrabri, which makes use of two 22 ft diam. mirrors moving on a track of over 600 ft diam. and has a resolving power of 0·0005 sec. of an arc; some results of the measurements of the size and temperature of a few stars were presented.

The possibility of using lasers as amplifiers in the intensity interferometer was considered. This is analogous to the use of masers as amplifiers in radioastronomy. From theoretical considerations of the signal to noise ratio in the stellar interferometer, the laser amplifier was shown to be a possibility only in the case of degenerate photon beams whose temperature is much higher than $h\nu/k$. The other papers presented at this session dealt with diffraction and phase contract image formation in partially coherent light.

Interferometry in Radioastronomy

The importance of interferometry in radioastronomy for attaining high resolving power and the different techniques used for this purpose were discussed. These are basically similar to optical interferometry, but the flexibility of the radio techniques and the long wavelength of the waves render all theoretically conceivable processes practicable. It was shown that the ring-shaped array of aerials, which is equivalent to an annular aperture in optics, gives all the information necessary to form an image that would be given by a filled-in array of the same outer dimension as the annulus. The method of extracting information and of guiding and preserving the phase coherence in such a system was described. The system is being applied to solar observations at wavelength 3·75 m. using an aperture 3 km. in diameter.

Interferometry in Metrology

The developments in interferometric measurement of length since the adoption of the light wavelength as the standard were reviewed. The limitations of the krypton isotope lamp and the recent researches to overcome these were described. The usefulness of end and line standards as intermediate in many length measurements was brought out and improved gauges of this type were described. The use of lasers in metrology, specially for precise measurement of long distances and for electronic fringe counting, was discussed. A comparatively simple, single frequency, He-Ne laser was reported which is suitable for use in metrology, as also a method of continuously monitoring and controlling the wavelength of the laser light by comparing it with that of the standard 86 Kr line with the help of a Fabry-Pérot interferometer. Some experimental arrangements for interferometric measurement of length were described, but these used the Michelson interferometer with fairly conventional fringe counting techniques. An interesting feature in one of these was the use of a multiple beam Fizeau type interferometer as the sensor for the automatic control of pressure and hence the wavelength of the light used.

A large ruling machine for producing diffraction gratings up to 18 in. in ruled width and 11 in. in groove length, now under test at the Massachusetts Institute of Technology, was described by Prof. G. R. Harrison. The novel features of this machine are interferometric servo control of the blank carriage in translation as well as in rotation about vertical and horizontal axes and the provision of two diamonds for simultaneous, phased-in double diamond ruling on one or more blanks.

New Interferometric Techniques

Shearing interferometry was one of the new techniques discussed. These interferometers can be made to give the wave front profile, the derivative of the wave front or the autocorrelation function of its complex amplitude. All the three classes of interferometers using birefringent as well as conventional types of beam splitters were described and the various uses of these interferometers, specially in interference microscopy and high resolution spectroscopy, were pointed out. The theory and applications of shearing the two wave fronts rotationally to different azimuthal angles, or the theta shearing, were discussed and several methods of realizing the theta shear were described. These largely made use of the double passing and polarization switching techniques in interferometry, developed in the National Physical Laboratory of India.

In interference spectroscopy it is advantageous to have an interferometer in which the tilt of the moving mirror does not alter the interference pattern. The polarization effects and their compensation in a class of interferometers having this property were discussed and the description was given of a balloon-borne Michelson type interference spectrometer for recording the air-glow spectra in the region 1-2·5 μ. Prof. A. Marachal presented a paper on a three-beam interferometer giving high sensitivity and fringe brightness. An interesting application of this is as an extremely sensitive spherometer. Among the other new techniques described, mention may be made of a method of automatic control of Fabry-Pérot type of interference filter having very narrow pass bands and of the use of a microwave interferometer for the detection of the diffraction substructure of the multiple beam fringes. This diffraction effect cannot be resolved in the optical region, but gives rise to the different modes of oscillation in lasers. The result of the microwave measurement agreed well with theoretical prediction.

Lattice Dynamics of Metals*

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THE vibrations of the constituent atoms are of fundamental importance for understanding the thermodynamic, elastic, optical, electrical and other physical properties of the crystalline solids. The theoretical and experimental study of lattice dynamical problems has been of interest to physicists almost continuously during the fifty years following the publication of the pioneering papers of Debye[1] and of Born and von Kármán[2] which laid the foundation of the modern theory of lattice dynamics. The past few years have seen the application of powerful new techniques, both theoretical and experimental, to the study of the dynamical properties of crystals, with a corresponding increase of interest in lattice dynamics[3]. One of the challenging problems in the theory of lattice dynamics is to give a satisfactory treatment of the lattice dynamics of metals. It is basically a many-body problem of a number of electrons interacting with the ions that constitute the lattice. Recently a good deal of progress has been made in this field and in this review an attempt is made to analyse a few simple models, which permit us to carry out a numerical calculation of the various lattice dynamical properties.

Anisotropic Continuum Dispersive Model

It is convenient to have a simple lattice dynamical model for a calculation of the properties of solids. An extremely simple model normally used in such calculations is the Debye model. In this model both the anisotropy and the dispersion of the lattice waves are neglected. The author and coworker[4] have recently taken account of both these factors in a simple way and have assumed a dispersion relation of the form

$$\omega_{q,i} = C_i \left(\frac{2Q}{\pi}\right) \sin \frac{\pi q}{2Q}$$

where C_i are the velocities of the sound waves with different polarizations given by the three roots of the third order Christoffel equation for a particular direction of the propagation vector $\boldsymbol{q}$. The Brillouin zone is replaced by a sphere of radius $Q = (6\pi^2 N)^{1/3}$ where N is the number of unit cells per unit volume.

The vibrational spectra, specific heats and Debye temperatures of copper and lithium were calculated on the basis of this model. The frequency spectrum of copper calculated by sampling method from 7770 points distributed in the Debye sphere is shown in Fig. 1, together with Jacobsen's calculated spectrum[5] from a force constant model fitted to his experimental dispersion curves obtained from diffuse X-ray scattering measurements. The calculated values of Debye temperature of copper from the spectrum evaluated on the anisotropic continuum dispersive model are shown in Fig. 2. Studies carried out in this department show that the anisotropic dispersive continuum model gives reasonable, though by no means detailed, agreement with the experiments. It is, therefore, suggested that the use of this model in a calculation of a physical property of a crystal in place of the usual Debye approximation will be more realistic. It is to be emphasized that more accurate and sophisticated models would burden such a calculation too much. This model has been used for calculating Grüneisen parameter[6] and Debye-Waller factor of copper (Sharma, K. C. & Joshi, S. K., unpublished data) and the results are encouraging.

Force Models

Many calculations on the lattice dynamics of metals employ force models in which selected group of atoms are supposed to interact with elastic forces[7-12]. The force constants pertaining to the relative motions of atoms are evaluated by correlating them to the macroscopic elastic data and depend upon the manner in which a particular force model has been built up. Different force models yield widely different values of the force constants between the neighbours of the same metal, and obviously bear little resemblance to the interactions actually present. Approximate agreement between the experimental and theoretical values of thermodynamic properties is achieved only because these properties are relatively insensitive to the finer details of the frequency spectrum. No valid reasons have been advanced to show that it is justified to represent a metal by a force model involving interaction between a selected group of atoms. At present a great improvement in this direction has been achieved. The atomic force constants are now derived by fitting them to the experimental dispersion curves obtained either by neutron spectrometry or by thermal diffuse scattering of X-rays. These studies have established the long-range nature of interatomic interactions in metals.

Phenomenological Models

Because of the difficulties involved in developing a fundamental microscopic theory, considerable effort has been devoted to the development of phenomenological theories[13-15]. In the simple model of de Launay[13], the effect of free electron gas is introduced by attributing to it a bulk modulus K_e and assuming that the gas can support no shear stress. Such an effect would influence longitudinal waves only. Bhatia[15] has carried out a similar investigation for cubic metals. He assumed that the forces on an ion in the lattice arise from a central interaction which is significant for nearest neighbours only and also from energies which depend on atomic

*Based on a talk given at the Symposium on Solid State Physics, held at the National Physical Laboratory, New Delhi, in April 1964.

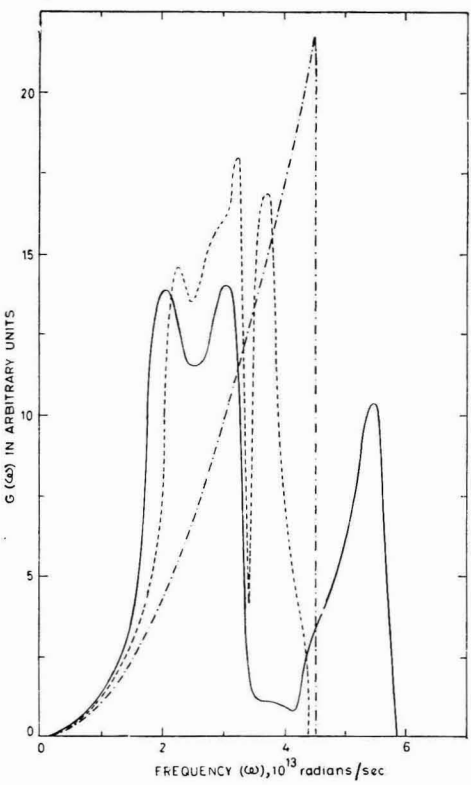

Fig. 1 — The lattice vibrational spectrum of copper [—, Spectrum obtained on the anisotropic dispersive continuum model; - - -, spectrum obtained by Jacobsen; —·—, the Debye spectrum]

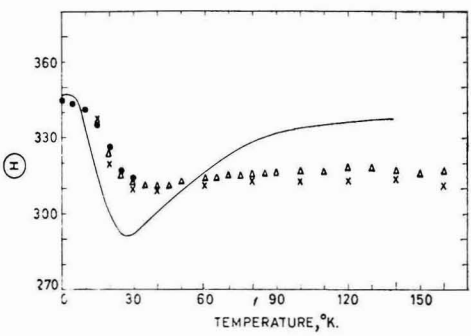

Fig. 2 — Debye temperature (Θ) versus temperature for copper [—, Theoretical curve obtained from the frequency spectrum shown in Fig. 1. Experimental values obtained by different workers: ●, Franck *et al.*[29]; △, Martin[30]; and X, Giaque and Meads[31]]

volume only and which are due to free electrons, i.e. Fermi and exchange energies. The absence of the periodicity in the dispersion curves as predicted by these theories indicates that these models, which do not even satisfy the symmetry conditions for the lattice, are not realistic.

The author and collaborators have recently propounded two semi-phenomenological models for the lattice dynamics of metals which are discussed in the following.

Model I — In this model we visualize a metallic crystal as a lattice of bare ions imbedded in a uniform cloud of electrons. We regard the energy of the crystal as a sum of two terms, which to a useful approximation can be calculated separately. One of the terms represents the central force between the ions and the other the volume forces originating from individual electron energies plus exchange and correlation terms. The energy due to central interaction is partly Coulombic and the non-Coulombic part arises from the interaction between the closed shells of neighbouring ions and from the Van der Waals forces. The potential energy of the crystal can be expanded in terms of the displacements and in the harmonic approximation, as

$$\Phi = \Phi_0 + \tfrac{1}{2} \sum_{m,n} \sum_{i,j} \Phi_{i,j}^{m,n} u_i^m u_j^n + \tfrac{1}{2} K_e \int \chi^2(\boldsymbol{r}) d\tau \qquad \ldots(1)$$

In Eq. (1), Φ_0 is the energy of the crystal with ions in their equilibrium position $\boldsymbol{R}^m$, u_i^m is the ith Cartesian component of the displacement $\boldsymbol{u}^m$ of the mth ion, and

$$\Phi_{i,j}^{m,n} = \frac{\partial^2 \Phi}{\partial r_i^m \partial r_j^n} \Bigg|_{r_i^m = R_i^m,\ r_j^n = R_j^n} \qquad \ldots(2)$$

are the force constants, K_e is the isothermal compressibility of the electron gas and χ, the compressive strain at the point $\boldsymbol{r}$ in the electronic medium is given by the relation

$$\chi(\boldsymbol{r}) = -\text{div}\ \boldsymbol{u}(\boldsymbol{r}) \qquad \ldots(3)$$

The ion-ion interaction depends on the dynamical matrix ϕ_{ij}. It is reasonable to assume that the interionic forces are rather local, i.e. they must act between nearest neighbours in the lattice. Such restrictive assumptions have to be made concerning the interatomic forces in order that the number of non-zero force constants required in the theory does not exceed the number of elastic constants. We assumed that the interatomic forces are central and limited to first and second neighbours. The typical dynamical matrices for b.c.c. and f.c.c. structures for such an interaction are given elsewhere by Sharma and Joshi[16,17].

From Eq. (1) the force on the ion at site O, $[(F_i^0)_{\text{ion}}]$, due to ion-ion interaction in the ith direction is given by

$$(F_i^0)_{\text{ion}} = -\frac{\partial \Phi}{\partial u_i^0} = -\sum_n \sum_j \Phi_{ij}^{0n} u_j^n \qquad \ldots(4)$$

Next we consider the electron-ion interaction. Because of the symmetry of the lattice it is profitable to partition the lattice into a set of space-filling

polyhedra. Following Wigner and Seitz[18], we replace the atomic polyhedra by spheres of radii r_0 and volume equal to atomic volume $\Omega = 4/3\ \pi r_0^3$. We assume that the displacement due to thermal motion in the medium of uniformly distributed electron gas at the point $\boldsymbol{R}^m + \boldsymbol{r}$ inside the Wigner-Seitz sphere centred around $\boldsymbol{R}^m$ is of the form

$$\boldsymbol{u}^m(\boldsymbol{r}) = \boldsymbol{e}A \exp i\{\boldsymbol{q}.(\boldsymbol{R}^m+\boldsymbol{r}) - \omega t\} \qquad ...(5)$$

In Eq. (5), $\boldsymbol{q}$ is the wave vector of the thermal waves ($q = 2\pi/\lambda$), ω the angular frequency, A the amplitude and $\boldsymbol{e}$ the polarization vector. The consequent compressive strain can be written from Eq. (3)

$$\chi^m(\boldsymbol{r}) = -i(\boldsymbol{e}.\boldsymbol{q})A \exp i\{\boldsymbol{q}.(\boldsymbol{R}^m+\boldsymbol{r}) - \omega t\} \qquad ...(6)$$

The mean value of χ^m in the Wigner-Seitz sphere is

$$<\chi^m> = -i(\boldsymbol{e}.\boldsymbol{q})A \exp i\{\boldsymbol{q}.\boldsymbol{R}^m - \omega t\} G(qr_0) \qquad ...(7)$$

where

$$G(x) = 3(\sin x - x \cos x)/x^3 \qquad ...(8)$$

Substituting from Eq. (7) in Eq. (1) and taking the time average, the volume-dependent potential energy of the crystal due to the conduction electrons becomes

$$\Phi_c' = \tfrac{1}{4}(\boldsymbol{e}.\boldsymbol{q})^2 A^2 G^2(qr_0) K_c V \qquad ...(9)$$

The force acting on the ions due to the compressibility of the electron gas is along the gradient of the compressive strain and hence along $\boldsymbol{q}$. The amplitude of ionic motion along the wave vector is $A(\boldsymbol{e}.\boldsymbol{q})/q$. Hence the part of the force on the mth ion which is due to electrons becomes

$$(\boldsymbol{F}^m)_{\text{electron}} = -CA\boldsymbol{q}(\boldsymbol{e}.\boldsymbol{q}/q^2) \exp i\{\boldsymbol{q}.\boldsymbol{R}^m - \omega t\} \qquad ...(10)$$

The constant C in Eq. (10) is obtained by equating the average potential energy of the harmonic motion which would be maintained by the force $(\boldsymbol{F}^m)_{\text{electron}}$ with potential energy given by Eq. (9) and we finally obtain

$$(\boldsymbol{F}^m)_{\text{electron}} = -AK_c\Omega\boldsymbol{q}(\boldsymbol{e}.\boldsymbol{q})G^2(qr_0) \exp i(\boldsymbol{q}.\boldsymbol{R}^m - \omega t) \qquad ...(11)$$

The calculation of the vibrational frequencies of the lattice is now quite a straightforward task. The equation of motion of an ion at the origin and having mass m is

$$m(\partial^2\boldsymbol{u}^0/\partial t^2) = (\boldsymbol{F}^0)_{\text{ion}} + (\boldsymbol{F}^0)_{\text{electron}} \qquad ...(12)$$

Combining this with Eqs. (4) and (11)

$$m\omega_q^2 u_{i,q} = \Sigma M_{ij}(\boldsymbol{q}) u_{j,q} \qquad ...(13)$$

The condition for the solubility of this set of equations is

$$\det\ |M - m\omega^2| = 0 \qquad ...(14)$$

For b.c.c. structure

$$M_{ii}/4 = \alpha' S_i^2 + 2\alpha(1 - C_1C_2C_3) + K_c a^3 G^2 q_i^2$$

$$M_{ij}/4 = 2\alpha S_i S_j C_k + K_c a^3 G^2 q_i q_j, \quad i,j,k \text{ all different}$$

and

$$S_i = \sin q_i a;\ C_i = \cos q_i a$$

Taking the long wavelength limit of Eq. (14) and then comparing with Christoffel equation of elasticity we obtain

$$K_c = C_{12} - C_{44}$$

$$\alpha = -aC_{44}$$

$$\alpha' = -a(C_{11} - C_{12})$$

Similar expressions can also be written for f.c.c. structure[17]. The theory was used to calculate the dispersion relations for lattice waves along symmetric directions in sodium and copper. Specific heat and Debye temperature were also calculated for copper. In Fig. 3 are presented the dispersion curves for sodium in three different directions, viz. [100], [110] and [111], and for a temperature of 90°K. calculated by the author and collaborators together with Toya's curves[19] and experimental data. The agreement with the experiment is quite good for both the theoretical models.

Model II — In this model, we picture the metal as a lattice of bare ions imbedded in a uniform cloud of electrons and regard the energy of the crystal as a sum of two parts, Coulombic and non-Coulombic. The Coulombic part takes care of Coulomb interaction between the ions and the ion-electron interaction which of course involves electron-electron interaction. The non-Coulombic part arises from the exchange repulsion between the closed shells of the neighbouring ions and from the Van der Waals forces.

In the absence of thermal motion the electrostatic potential $\Phi(\boldsymbol{r})$ is constant in time. Because of the lattice waves Φ will become a function of space and time coordinates, let

$$\Phi(\boldsymbol{r}) = \Phi_0 + \varphi(\boldsymbol{r}) \qquad ...(15)$$

We evaluate $\varphi(\boldsymbol{r})$ for a given ionic displacement by Fermi-Thomas method. The Poisson's equation for $\Phi(\boldsymbol{r})$ is

$$\nabla^2\Phi = \nabla^2\varphi(\boldsymbol{r}) = -4\pi\rho(\boldsymbol{r}) = -4\pi[Zc\rho_i(\boldsymbol{r}) - en(\boldsymbol{r})] \qquad ...(16)$$

Here $\rho_i(r)$ is the number density of ions of charge Zc and $n(\boldsymbol{r})$ is the electronic number density. The term $n(\boldsymbol{r})$ can be written from Fermi-Thomas method[20]

$$n(\boldsymbol{r}) = \frac{\{2mc\Phi\}^{3/2}}{3\pi^2\hbar^3} = n_0 + \Delta n(\boldsymbol{r}) \qquad ...(17)$$

where

$$\Delta n(\boldsymbol{r}) = \frac{(2mc)^{3/2}}{2\pi^2\hbar^3}\Phi_0^{1/2}\varphi(\boldsymbol{r}) = K^2\varphi(\boldsymbol{r}) \qquad ...(18)$$

with

$$K^2 = \frac{(2mc)^{3/2}}{2\pi^2\hbar^3}\Phi_0^{1/2} \qquad ...(19)$$

Let the displaced position of the ion normally at $\boldsymbol{R}_l^0$ be

$$\boldsymbol{R}_l = \boldsymbol{R}_l^0 + \boldsymbol{u}_l$$

Then

$$\rho_i(\boldsymbol{r}) = \sum_l \delta(\boldsymbol{r} - \boldsymbol{R}_l^0 - \boldsymbol{u}_l) \qquad ...(20)$$

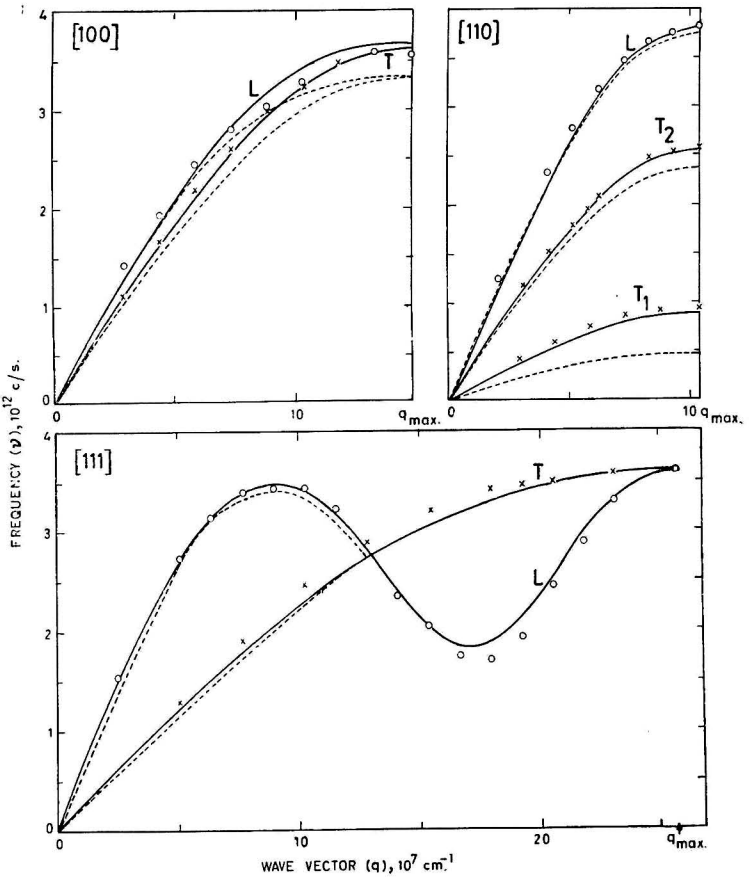

Fig. 3 — The dispersion curves for sodium at 90°K. in [100], [110] and [111] directions [—, Calculations based on model proposed by author and collaborators; ---, Toya's calculations; L and T refer to the longitudinal and transverse polarization branches; T_1 and T_2 denote the two different transverse branches along the [110] propagation direction; ○ and X represent the experimental values of Woods *et al.*[21] for the longitudinal and transverse polarization branches respectively]

Substitution of Eqs. (17), (18), (19) and (20) in Eq. (16) yields the Yukawa equation

$$(\nabla^2-K^2)\varphi(\boldsymbol{r}) = -4\pi Ze\Sigma_l\delta(\boldsymbol{r}-\boldsymbol{R}_l^0-\boldsymbol{u}_l)+4\pi en_0 \quad ...(21)$$

From the solution of this equation we can write or the Coulomb potential energy of the lth ion:

$$W_l^C = Ze\varphi(\boldsymbol{R}_l^0+\boldsymbol{u}_l) = Z^2e^2\sum_{l'\neq l}\frac{\exp(-K|\boldsymbol{R}_l^0+\boldsymbol{u}_l-\boldsymbol{R}_{l'}^0-\boldsymbol{u}_{l'}|)}{|\boldsymbol{R}_l^0+\boldsymbol{u}_l-\boldsymbol{R}_{l'}^0-\boldsymbol{u}_{l'}|}-\frac{4\pi Ze^2n_0}{K^2} \quad ...(22)$$

The expression for the non-Coulombic part of the potential energy, W_l^R, is, as usual, based on Born and Mayer type repulsive potential between the ions and is given by

$$W_l^R = A\sum_{l'\neq l}\exp\{(2r_B-|\boldsymbol{R}_l^0+\boldsymbol{u}_l-\boldsymbol{R}_{l'}^0-\boldsymbol{u}_{l'}|)/\rho\} \quad ...(23)$$

where A, r_B and ρ are constants for a particular crystal. The equations of motion of the central ion have the form

$$m(\partial^2u_{0i}/\partial t^2) = -\frac{\partial W_0^C}{\partial u_{0i}}-\frac{\partial W_0^R}{\partial u_{0i}} \quad ...(24)$$

where m is the mass associated with each ion. The displacement of the lth ion due to lattice wave of wave vector $\boldsymbol{q}$ is given as

$$\boldsymbol{u}_l = N^{-1/2}\boldsymbol{e}_q\{a_q\exp(i\boldsymbol{q}.\boldsymbol{R}_l^0)+a_q^*\exp(-i\boldsymbol{q}.\boldsymbol{R}_l^0)\} \quad ...(25)$$

where a_q is the amplitude of the wave, $\boldsymbol{e}_q$ its polarization vector and N the number of ions per unit volume. Algebraic manipulation of Eqs. (22)-(25) gives the following type of equation for components of $\boldsymbol{u}_0$

$$\left.\begin{aligned} m\omega^2u_{0i} &= \Sigma_j M_{ij}u_{0j} \\ \text{where} \quad M_{ij} &= M_{ij}^C+M_{ij}^R \end{aligned}\right\} \quad ...(26)$$

with

$$M_{ij}^{C} = Z^2e^2 \sum_{l\neq 0} \frac{e^{-KR_l^0}}{R_l^{03}} (1-\cos \boldsymbol{q}.\mathbf{R}_l^0)$$

$$\times \left[-(1+KR_l^0)\delta_{ij} + \{ KR_l^0)^3 + 3KR_l^0 + 3\} \frac{X_l Y_l}{R_l^{02}} \right] \quad ...(27a)$$

and

$$M_{ij}^{R} = \frac{A}{\rho} \sum_{l\neq 0} \frac{e^{(2r_B - R_l^0)/\rho}}{R_l^0} (1-\cos \boldsymbol{q}.\mathbf{R}_l^0)$$

$$\times \left[-\delta_{ij} + \left(\frac{R_l^0}{\rho} + 1 \right) \frac{X_l Y_l}{R_l^{02}} \right] \quad ...(27b)$$

In Eqs. (27a) and (27b) X_l, Y_l and Z_l stand for R_{lx}^0, R_{ly}^0 and R_{lz}^0 respectively. Again the condition of solubility of the set of Eqs. (26) determines the three distinct frequencies $\omega_j(q)$ corresponding to one value of $\boldsymbol{q}$.

The dispersion curves were calculated for sodium along symmetric directions. The summations in Eq. (27) were carried up to ninth neighbours for M_{ij}^{C} and up to second neighbours for M_{ij}^{R}, after which they become negligible. The effect of truncating the sum in M_{ij}^{C} at ninth neighbours was investigated and truncation errors were found negligible. The agreement of the calculated curves with the experimental results of Woods *et al.*[21] was fairly satisfactory in view of the approximate nature of the theory.

Recently fundamental and potentially more powerful approaches to the lattice dynamics of metals have been developed by Toya[19], Harrison[22] and Cochran[23]. Toya has used the Hartree-Fock approximation to calculate the frequencies of the normal modes of monovalent metals for lattice waves propagating along symmetric directions. The interaction is taken to be the sum of (i) the Coulomb interaction between the ions, (ii) the overlap interaction between the ions, and (iii) the ion-electron and electron-electron interactions. From the equations of motion we can write an equation similar to Eq. (26) with

$$M_{ij} = M_{ij}^{C} + M_{ij}^{R} + M_{ij}^{E} \quad ...(28)$$

The three terms in Eq. (28) originate from the three interactions mentioned above. M_{ij}^{C}, due to the Coulomb interaction between ions, is evaluated by Kellermann's method[21] just as in the case of alkali halides. The term M_{ij}^{R} is given here also by Eq. (27b) and the last term is given by

$$M_{ij}^{E} = \frac{4\pi e^2}{\Omega} \left[\tfrac{1}{3}\delta_{ij} - \sum_{Q} \frac{(q_i+Q_i)(q_j+Q_j)}{|\boldsymbol{q}+\boldsymbol{Q}|^2} H(t) f(t) \right] \quad ...(29)$$

with

$$t = \frac{|\boldsymbol{q}+\boldsymbol{Q}|}{2k_F}$$

and

$$f(t) = \tfrac{1}{2} + \frac{1-t^2}{4t} \log \frac{1+t}{1-t} \quad ...(30)$$

where k_F is the wave vector of the electron at the Fermi surface. The function $H(t)$ involves a number of electronic parameters of uncertain value. The nature of $f(t)$ implies that when

$$|\boldsymbol{q}+\boldsymbol{Q}| = 2k_F, \ |\mathrm{grad}_q\, \omega| \to \infty$$

This anomaly was predicted by Kohn[25]. According to Kohn the phonon dispersion curves in a metal should show kinks at points where the slopes of the dispersion curves become infinite. Their position is determined by the size and shape of the Fermi surface. Thus if the phonon dispersion curves could be measured with sufficient accuracy for different directions in the Brillouin zone so that the kinks could be observed, it would then be possible to map out the Fermi surface. Kohn's discussion has been extended and generalized recently by Woll and Kohn[26] who have made a careful determination of the magnitude of the effect. Their conclusion is essentially that the kinks in the phonon dispersion curves of metals are probably too small to be observed experimentally. Nevertheless, kinks which have been interpreted as due to the Kohn effect have recently been found in the dispersion curves for the longitudinal branches in the [110] and [111] directions in lead by Brockhouse *et al.*[27] by means of neutron spectrometry. The positions of the kinks are consistent with a Fermi surface which is nearly spherical and contains four electrons. The results of Brockhouse *et al.* have been confirmed by Paskin and Weiss[28] who used the thermal diffuse scattering of X-rays to study the phonon dispersion curves in lead. However, the recent work of Harrison[22] has suggested that the kinks observed by Brockhouse *et al.*[27] are not images of the Fermi surface, but are a more complicated manifestation of the electron-phonon interaction.

Summary

The current trends in the theory of lattice dynamics of metals are briefly reviewed, with particular emphasis on the work being carried out by the author and his collaborators. A number of approaches to the study of the dynamical properties of crystals have been made, based on lattice dynamical models such as the anisotropic continuum dispersive model, force models, semi-phenomenological models, etc. The anisotropic dispersive continuum model is found to yield satisfactory results as regards frequency spectra and thermal expansion of solids, and it is suggested that it is a convenient and reliable model to use in the calculation of many other physical properties dictated by lattice vibrations. The inadequacy of current force models is pointed out and the phenomenological models of Bhatia and de Launay are briefly discussed. Two semi-phenomenological models for monovalent metals, recently proposed by the author and his collaborators, are discussed in detail and the results are compared with existing experimental data on neutron spectroscopy and specific heat. These models visualize a metallic crystal as a lattice of bare ions embedded in a uniform cloud of electrons. The first of these models treats the electronic effect in a way similar to that of de Launay and the second model uses the Fermi-Thomas method. The first

model explains the experimental results very well. The potentially powerful approach developed in recent years by Toya to the study of lattice dynamics of metals is outlined and the Kohn anomaly is discussed.

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Summer School in Advanced Chemical Engineering

A Summer School in Advanced Chemical Engineering will be held at the Regional Research Laboratory, Hyderabad 9, from 14 to 26 June 1965, under the auspices of the Council of Scientific & Industrial Research. Invitations have been extended to various institutes and industries in India, interested in the field of chemical engineering, to nominate members from their organizations for undergoing training at the summer school. Advanced lectures covering various aspects of chemical engineering will be delivered by experts from all over India. Practical demonstrations, mostly on pilot plant scale, in specialized topics are also included in the course for the benefit of the trainees.

Some Aspects of Microbial Iron Metabolism

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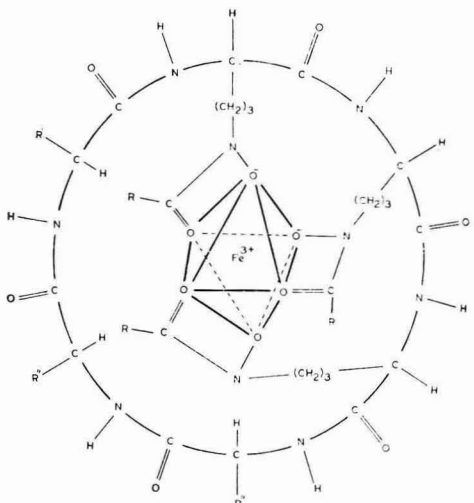
THOUGH one is not quite certain whether to consider iron as a macronutrient or a micronutrient, there is no ambiguity in regard to its important role in animal and plant nutrition. Iron deficient anaemias[1] and chlorosis[2] are well-documented cases of non-availability of this element in animals and plants respectively. At the biochemical level, iron, as a constituent of haeme and as such in haeme proteins, as an integral part of non-haeme iron enzymes and as an activator of various other enzymatic reactions, has many important functions to perform in the living cell[3]. The presence of this metal in nucleic acids[4] may point to yet another functional role for this element. As is the case with several other essential metabolites, which are required to perform various functions, a control mechanism has to operate for a judicious supply in the case of iron as well. Consequently ferritin fills up this role as a key storage compound of iron in animal systems.

The above picture is more or less true for microbial systems as well. The decrease in key iron enzymes, porphyrin secretion and the fall in growth in microorganisms due to iron deficiency are well known[5,6]. In addition to the well-recognized enzymatic sites, an iron protein, ferredoxin, recently isolated from microbial and plant systems[7,8], is implicated in electron transport, being the most electronegative electron carrier known in cellular oxidation-reduction reactions. Despite all these findings, the control mechanisms operating in iron transport in microorganisms are not very clear and only recently it has been possible to show that certain iron compounds are involved in these control processes. Further, microorganisms with their enormous potential for adaptation and survival capacities are ideal material to look for such mechanisms, especially under conditions of non-availability of this element.

Sideramines and Sideromycins

In 1952, Neilands[9] isolated an iron containing compound from the cells of *Ustilago sphaerogena*. It has been given the name ferrichrome and subsequently a closely related compound having a profound binding affinity for iron was isolated from the culture fluid of the same organism grown under iron deficient conditions. The latter has been referred to as ferrichrome-A[10]. The production of an iron binding compound under conditions of iron deficiency would be a metabolically useful act for the organism and this stimulated the interest in the study of these compounds in detail. Ferrichrome has been considered to be a heteromeric peptide[11] containing glycine and the unique amino acid, δ-N-hydroxy ornithine[12], carrying an acyl moiety. The only other instance of the natural occurrence of a ω-hydroxyamino acid, reported earlier, has been the detection of ε-N-hydroxy lysine in mycobactin, a growth factor for *Mycobacterium johnei*[13]. The hydroxamic acid moiety of δ-N-hydroxy ornithine has an important function, for it binds the iron. The amino acid sequence in the ferrichromes has been studied[14] and a three-dimensional structure has been proposed on the basis of several physicochemical data. Fig. 1 represents a structural model for the ferrichrome type compounds[15].

Ferrichrome-A differs from ferrichrome in that it contains serine in addition to glycine and ornithine, has less nitrogen and iron and the acyl moiety is replaced by β-methyl glutaconic acid[16]. Compounds closely related to the ferrichromes have been isolated from Aspergillus and Penicillium species which have been named as ferricrocin, ferrichrysin, ferrirubin and ferrihodin[17]. These compounds contain ornithine, serine and glycine but show differences in the molar ratios of these amino acids as well as having different substituent groups at R, R′ and R″ in the model represented in Fig. 1. Certain other compounds which either contain iron or have a profound binding affinity for iron may also be considered here. Coprogen[18], the chemical nature of which is not clear, has been isolated from Actinomyces ferments. Terregens factor[19], having a profound binding affinity for iron, has been isolated from *Arthrobacter terregens*. On hydrolysis of this



Ferrichrome: R = CH_3; R′ = R″ = H. Ferrichrome-A:

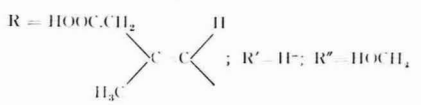


Fig. 1 — Structural model for ferrichrome type compounds

factor the ninhydrin positive spots obtained have been identified as glutamic acid, glycine, α-alanine, valine, leucine, proline, lysine and arginine. Yet another group of compounds is the ferrioxamines[20], isolated from Streptomyces. Despite differences in gross structure, the biological property that marks this group of compounds is their growth promoting ability of certain microorganisms and their mutual replaceability as a growth factor for these organisms.

As against these, another group of compounds which are generally growth inhibitory and antagonize the effect of the former list of compounds is the ferrimycins, isolated from *Streptomyces griseoflavus*. A classification has been proposed for these compounds which have the characteristic hydroxamate structure at the iron binding site. The ferric polyhydroxamate class of compounds have been referred to as Siderochromes, the growth promoting ones being designated as sideramines, and the growth inhibitory as sideromycins[20]. Compounds like albomycin[21] and grisein[22] fall in the latter group.

Ketose-Amino Acids and Itoic Acid

Neilands in his review[11] has suggested that the ketose-amino acids are yet another novel iron binding sites of probable metabolic importance. The iron binding compound secreted by *Bacillus subtilis* under conditions of iron deficiency has been identified as 2,3-dihydroxy benzoyl glycine (itoic acid)[23].

Ferrichrome and Its Metabolic Importance

Considerable evidence has accumulated in the case of ferrichrome pointing to its important role in iron metabolism. As already indicated, the great binding affinity for iron and the elaboration of the iron binding moiety under conditions of iron deficiency warrant such a role for this compound. It has been found that there exists a reciprocal relationship between the ferrichrome and cytochrome-*c* contents in the cells of Ustilago which is governed by the zinc status of the medium[11]. Under conditions of zinc deficiency the cells contain little cytochrome-*c* but yield relatively large amounts of ferrichrome. With increase in the zinc status there is a drop in the ferrichrome content concomitant with the synthesis of cytochrome-*c*. Later investigations have thrown light on the relation between ferrichrome and cytochrome contents, but the role of zinc is not clear. Ferrichrome has been found to be a growth factor for certain microorganisms like *Arthrobacter terregens*, *Arthrobacter flavescens*, *Mycobacterium johnei*i, *Piloholus klenii*, *Microbacterium lacticum* 8181 and *Arthrobacter* JG 9. But a much larger number of organisms have been found to produce growth factors of the hydroxamate type or at least answer for the presence of bound hydroxylamine. The participation of these hydroxamates in the iron metabolism of the parent organism, however, remains to be proved. Detailed studies with *Arthrobacter* JG 9 have revealed that it has an absolute requirement for ferrichrome to maintain normal growth and catalase activity even though inorganic iron may be provided in the medium. The ferrichrome requirement can be met with by providing 100 times its amount of haemin[24]. Ferrichrome-Fe^{59} has been shown to get incorporated into catalase which is repressed by the addition of haemin in growing cultures[25] of *Arthrobacter* JG 9. It has also been demonstrated that ferrimycin-A inhibits catalase synthesis in *Arthrobacter* JG 9 when supplemented with ferrichrome but not when provided with haemin. All these results suggest that ferrichrome is necessary for haeme synthesis and ferrimycin-A acts by blocking this step. Cell-free extracts of *Rhodopseudomonas spheroides* have been shown to be able to synthesize haemin when incubated with an oxidizable substrate, protoporphyrin IX and iron as ferrichrome[26].

The biological activity of the ferrichrome compounds as ' coenzymes in iron transport ' has a bearing to the affinity of these compounds for ferric and ferrous iron. Ferrichrome would bind ferric iron with a stability constant about 10 times that of EDTA. But it would bind ferrous iron, if at all, very weakly. Neilands has envisaged a mechanism for the release of iron from ferrichrome involving reduction and the iron-free moiety can bind ferric iron in turn giving the parent compound[11]. Evidently the organism has to possess a mechanism, probably an enzymatic one for the release of iron from ferrichrome. An enzymatic mechanism can also ascribe a specificity as to the nature of the organic iron that can be utilized. For example, only ferrichrome and certain other members of its category like aspergillic acid, Nocardamin, Coprogen, Terregens factor, Grisein and Mycobactin can serve as organic iron sources for *Arthrobacter* JG 9; but ferrichrome-A and certain other synthetic secondary hydroxamates are poor sources of iron for the same organism[24]. Ferrichrome-A is 100 times less active as a growth factor for *Arthrobacter terregens* as compared to ferrichrome.

Information is also available as to the mode of breakdown of the ferrichromes when they serve as sole carbon and nitrogen sources. This has been rendered possible by the isolation of an unidentified Psuedomonas which can utilize the ferrichromes as sole carbon and nitrogen sources. It is indicated that initially the cyclic peptide rings are broken to yield simpler hydroxamates which are then deacylated, perhaps after reduction to the corresponding N-substituted amides. The enzymes involved in this breakdown are intracellular[27].

New Iron Binding Compounds

Work in this laboratory[28] has led to the isolation of yet another iron binding compound from *Neurospora crassa* Em 5297a. The iron binding compound has been detected in the culture fluid when the organism is grown under conditions of iron deficiency whether direct or indirect. Earlier studies with this organism[29,30] have revealed that cobalt toxicity can give rise to a conditioned iron deficiency and accordingly the iron binding compound has been detected under these conditions as well.

The compound isolated as the iron complex from the culture fluid after adding iron as ferric chloride, ammonium sulphate saturation, benzyl alcohol extraction and further purification on cellulose column

TABLE 1 — R_f VALUES OF FERRICHROME, FERRICHROME-A AND THE ISOLATED IRON COMPLEX

Solvent system	Ferri-chrome	Ferri-chrome-A	New complex
Butanol-acetic acid-water (4:1:1; ascending)	0·38	0·44	0·56
Methanol-water (80:20; ascending)	0·79	0·72	0·88

has been found to be homogeneous by paper chromatographic and electrophoretic criteria. The iron complex is readily soluble in water, methanol and ethanol, but insoluble in ether, chloroform and acetone. The data presented in Table 1 indicate that the complex has a different chromatographic mobility as compared to ferrichrome or ferrichrome-A.

Hydrolysis (6N-hydrochloric acid) of the iron complex has revealed the presence of 9 ninhydrin positive spots. The major ones correspond to ornithine, glutamic acid, glycine, serine and alanine. Minor ones correspond to threonine and aspartic acid. The complete and exact amino acid composition of the complex is under investigation. All these properties indicate the new compound to be different from the ferrichrome compounds or others reported earlier. But as regards the binding affinity for iron it shares the property of the ferrichrome compounds. The iron complex has a broad absorption maximum around 440 mμ. In dilute aqueous solution the colour is discharged by the addition of dithionite and the colour is regained on subsequent aeration. The compound evidently binds ferric iron and even prolonged extraction with 8-hydroxyquinoline fails to remove the iron from the complex. But on reduction the iron can be complexed easily by α,α′-dipyridyl or orthophenanthroline. This would indicate that the compound binds ferrous iron, if at all, very weakly. The ferric iron from the complex can be removed by alkali treatment with sodium hydroxide and the iron-free moiety on subsequent neutralization can again bind iron to give a coloured complex, though it has not been established to be the parent compound. The preparations isolated under conditions of cobalt toxicity and straight iron deficiency appear to be the same on the basis of chromatographic behaviour and qualitative amino acid composition.

It has also been observed that under conditions of iron deficiency an acid producing strain of *A. niger* secretes iron binding compounds into the media. Neilands[11] had detected earlier the production of an iron binding compound by *A. niger*, when grown under conditions of iron deficiency and suggested that it may be similar to ferrichrome compounds. It has been established that the compound secreted by *A. niger* (M 3574 and M 3573) is ferrichrome[17]. But the final preparation obtained from *A. niger* in this laboratory (Subramanian, K. N., Padmanaban, G. & Sarma, P. S., unpublished data) has been found to be ninhydrin positive, whereas the ferrichrome compounds are ninhydrin negative. Subsequent chromatography on paper in neutral solvents has revealed that *A. niger* iron compound isolated in this laboratory has more than one component and paper electrophoresis in pyridine-acetic acid buffer (*p*H 6·2) has revealed that at least 4 distinct components, each component carrying iron, are present. Further investigation to characterize these components is in progress. The variable results obtained may be due to strain differences in the experimental organism. Earlier it has been shown that the iron deficient Ustilago produces several iron binding compounds of which ferrichrome-A is the major component[10].

Conclusion

Isolation of iron binding compounds from various microorganisms proves the generality of the phenomenon and explains the survival capacities of these microflora and at the same time demands a controlling effect of these compounds on their iron metabolism. Neilands[11] has suggested the terms autosequesteric and anautosequesteric, ascribing the former to systems that can synthesize their iron binding compounds and the latter to those that do not have the capacity to do so. From the above discussion it is clear that *Neurospora crassa* can be classified as autosequesteric and *Arthrobacter* JG 9 as anautosequesteric, for the latter requires the obligatory presence of ferrichrome for normal growth and catalase activity. If this type of organic iron is necessary to facilitate iron sequestration and transport, it is evident that it should be present at least in small amounts in an organism growing under normal conditions. Ferrichrome itself is a natural metabolite of Ustilago and ferrichrome-A is the iron binding moiety secreted under conditions of iron deficiency. Just the same way, there can be little doubt that Neurospora synthesizes its own organic iron of this type when provided with inorganic iron and under conditions of non-availability of iron, the iron binding moiety either as such or in a modified form gets secreted into the medium. Neilands[23] in a discussion of the possible factors involved in this metabolic adjustment lists the following: (1) The biosynthesis of specific ferric complexing agents, normally competitively inhibited and maintained at a low level by the presence of a variable amount of a ferric chelate, becomes a major metabolic activity of the cell; (2) the deficiency of iron creates a metabolic block, the latter being manifested by the appearance of iron complexing products which normally require iron for their metabolism; and (3) the new substances produced in iron deficiency are intended to serve, either as such or as the ferric complex, as a by-pass for electron transport around the normal cytochrome system.

The evidences so far obtained make the last-mentioned possibility rather remote. It is quite conceivable that iron may be necessary for the metabolism of the iron complexing agents. For example, preformed itoic acid is rapidly removed from *B. subtilis* fermentation following the addition of iron. In view of the metabolic potency of the ferric chelates as iron donors for the organisms, it can as well be that the relation between the iron binding moiety and iron is mutual. The chelate formed under

normal conditions in the cell probably plays a key role in iron transport and the iron-free moiety which cannot be metabolized in the absence of iron finds its way into the culture fluid, thus assuming a survival function.

Though no systematic search has been made to look for iron binding or iron containing compounds of the type discussed in the present review, in plant and animal systems, evidence has been presented to indicate that plant systems do have a requirement for chelated iron and recently it has been shown that ferrioxamin-B is absorbed and translocated in tomato plants from nutrient solution. The chelated iron is transported to the upper parts of the tomato plants more rapidly than ionic iron[31]. There is a report[32] that iron pigments have been noticed in the gut of ' conventionalized guinea-pigs ' deliberately contaminated with normal guinea-pig intestinal microflora but not in that of germ-free animals. It is probable that even in animal systems these iron binding or iron containing compounds may be detected as a result[11] of microbial elaboration.

An aspect of practical significance has also emerged from a study of the iron binding or iron containing compounds. The sideromycins have great antibiotic potential. Danomycin[33], a recently isolated antibiotic, has inhibitory properties towards gram positive bacteria, and is an iron polypeptide related to the sideromycins. Thus it is evident that while these compounds serve an important role in the iron metabolism of the parent organism, some of them at least can prove to be potent antibiotics to certain other organisms.

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Nematodes in Relation to Diseases of Coconut Palms

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INSECT pests, nematodes, fungi, bacteria and viruses have been implicated in various diseases of coconut palms now rampant in different parts of the world[1,2]. However, the aetiology of some of the most destructive diseases such as 'Cadang-cadang' of Philippines, 'Lethal yellowing' (unknown disease) of Jamaica, 'Kaincope disease' of Togo and 'Root (wilt)' disease of Kerala remains mostly unknown. Symptoms, general course and infectious nature of these diseases suggest that they may be of virus origin. Martyn[3], who investigated the Lethal yellowing in Jamaica, suggested that a soil-inhabiting organism might carry the pathogenic virus from tree to tree. His suggestion was based on the observation of the rapid spread of this disease among the trees which grew together in certain soil types. Among a variety of soil organisms, nematodes probably deserve particular attention in being able to play such a role; for they have already been demonstrated to be vectors of soil-borne viruses of plant diseases by various workers and the pertinent literature has been reviewed by Raski and Hewitt[4]. In addition to serving as pathogens by themselves, nematodes are also known to be potential components in various plant disease complexes involving bacteria and fungi. It is the purpose of this paper to briefly review the available literature on nematodes known to be associated with coconut palms, and to discuss and indicate further scope for nematological research in relation to coconut palm diseases. It may be pointed out that literature on nematodes attacking coconut palms is extremely limited and consequently any discussion on nematode-palm relationship can profitably be made only in the light of investigations on other phytoparasitic nematodes.

Nematodes Associated with Diseases of Coconut Palms

Parasitic Nematodes

Very little is known about species of nematodes involved in diseases of coconut palms. This lack of information may be attributed to the fact that either too little research has been done in this field or nematodes infesting coconut trees are too limited in their distribution. More extensive search for existing literature or future research can tell which one of these alternatives is right.

Rhadinaphelenchus (= Aphelenchus) cocophilus

This nematode has been implicated in three diseases.

Red-ring disease — This is known to occur in Trinidad, British Guiana, Venezuela, Columbia, Tobago, Panama, Honduras and Brazil. The presence of nematodes in various tissues of diseased palms was first detected by Nowell[5] on the island of Grenada, British West Indies. Cobb[6] identified these worms as *Aphelenchus cocophilus*. Further investigations conducted by Nowell[7,8] led to the conclusion that the nematodes are pathogenic and that they are responsible for red-ring disease of coconut palms. Ashby[9] reviewed the then existing literature on red-ring disease together with the results of his own investigations.

The adult nematodes measure on an average 1 mm. in length, the males being slightly shorter than the females. They are found in large numbers throughout the red zone of the stem as well as in the white meristem of the upper extremities of the stem and embryonic leaves. The eggs are laid in living tissues. However, in roots which are also heavily infested by these worms, eggs are seldom noticed. According to Oostenbrink[10] the nematode has tremendous reproductive capacity and the population level may reach densities up to 108,000 per 10 g. stem tissues of affected palms.

The red-ring disease, which derives its name from the circular zone of red or orange tissues, as seen in transections of the stem of diseased trees, is characterized by non-specific symptoms such as progressive yellowing and wilting of leaves, withering and death of growing point and inflorescence, and discoloured tissues between the hard cortex and internal strand of infested roots.

Nowell[5] thought that the roots were the primary site of infection. In a later publication[11], however, he considered root infection as secondary to stem. Preliminary observations made by Fenwick and Maharaj[12] indicated that initial infection of roots occurs some distance from the bole and spreads inwards, and that the nematode can remain in the root system for a considerable period of time before invading the stem. They also obtained some evidence as to the transmission of the nemas from palm to palm via root system. By root sampling a large number of apparently healthy young trees, Fenwick and Maharaj[13] showed that infection can take place between roots lying in proximity to each other. From studies based on 106 trees afflicted with red-ring disease, Fenwick[14] reported again that infection can start in either the root system or in the upper part of the trees, the relative frequency of which remains to be determined. Further observations of Fenwick and Maharaj[15] on a number of infected trees at weekly intervals revealed that in some cases original site of infection was in a petiole, while in other cases it started near the base of the stem. It has been pointed out by Fenwick[16] that fallen nuts sometimes become infected from the soil and the use of such nuts as seeds is probably the means of introducing the disease to new localities.

The nematode infection at the aerial parts of the palm is mediated by the palm weevil, *Rhynchophorus palmarum* L. As early as 1922, Cobb[17] reported

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that this insect could serve as a vector of *Rh. cocophilus*. He observed that weevils visiting the trees readily leave the nemas in their tunnels, in the leaf axils or in the cracks at the base of the leaves. Since Cobb made these observations, extensive research has been done on the entomological aspect of red-ring disease. Investigations by many workers[18-21] have shown that this insect decidedly plays an important role in the spread of the disease. Recently Hagley[22] presented evidence to the effect that there is a correlation between the incidence of red-ring disease and palm weevil infestation. Adult palm weevils collected from coconut trees have been found to carry a large number of this nematode. It was further observed that the nemas were carried both externally in fragments of infected tissues adhering to the body surface of the insect, in which they could stay alive for 2-3 days, and internally in the digestive tract where they could remain as long as 10 days. Examination of faeces of the weevils, fed on diseased tissues, has indicated that the nematodes could pass through the gut of weevils in fairly healthy condition. In all these cases the insect appears to serve as a mechanical carrier. However, the possibility that the palm weevil may serve as an alternative host of *Rh. cocophilus* is also being investigated by Fenwick[23].

Experimental transmission of red-ring disease by adult palm weevils has also been demonstrated. Insects fed on diseased tissues for 18-24 hr were confined on the internodal region of the stem of healthy trees for 28-120 hr. The insects seemed to deposit fragments of infected tissues and contaminated faeces at the bases of petioles of the trees whence the parasites reach the soft internal stem tissues. Transmission via the mouth parts of weevils appeared to be ineffective.

Goberdhan[24] has made some interesting experimental observations on the damage mechanism of red-ring disease. It has been demonstrated that there is a fairly thermostable toxic substance in the infected red-ring tissue which can induce wilting in a variety of plants including tomato. Further tests, designed to determine whether this substance is produced by the nematode or by the plant in response to infection, indicated that it is produced as a result of tissue breakdown following nematode invasion.

With the aid of gravity injection equipment, Fenwick and Maharaj[25] conducted certain experiments, the results of which showed that coconut trees suffering from red-ring disease absorb less water than do healthy trees. This may be ascribed to partial blockage of the vascular strands in the infected areas or to the direct effect of toxins which lower the absorptive efficiency of leaves in affected trees.

Investigations are also under way on the control of red-ring disease. According to Fenwick[21] the most important finding is that organophosphorus compounds proved to be highly nematicidal. The use of organophosphorus insecticides for weevil control appears to serve a dual purpose since the chemicals might not only destroy the palm weevils but also kill any nematode which may be deposited on the trees by them.

It is interesting to note that the oil palm, *Elaeis guineensis* Jacq., also suffers from red-ring disease to the same extent as the coconut palm, *Cocos nucifera* L. Oostenbrink[10] has reported that certain plantation of oil palms in Venezuela lost 35 per cent of its trees within ten years. Slightly different symptomatically from that of coconut palms, the disease has the general course and results of infestations. The nematode's reproductive capacity is also remarkable in reaching a density up to 50,000 per 10 g. stem tissue of oil palm. The distribution pattern of nematodes within the stem and leaf petioles is, however, typical. As in the case of coconut palm, adult palm weevil, *Rh. palmarum*, seems to carry the nemas from tree to tree and thus serves as a vector.

Bud-rot of areca palms — Rh. cocophilus (=*Aphelenchoides cocophilus*) has been reported by Thirumalachar[26] in association with bud-rot of areca palms in Mysore, India. Some doubt, however, has been expressed as regards the taxonomic status of the nematode associated with bud-rot. It would be desirable to re-study the nematodes involved in this disease from a taxonomic point of view.

'Little leaf' — This disease, associated with both coconut and oil palms, is characterized by the leaves being reduced in size and standing stiffly upright. Little leaf is known to occur in Trinidad, Tobago, Venezuela and certain parts of Congo, Africa. Its probable occurrence in Brazil and Sumatra has been reported by Da Matta[27] and Donkersloot[28] respectively. Recently van Hoof and Seinhorst[29] studied little leaf disease in Surinam. The symptoms of the disease according to these authors are: "... The pinnae were shorter than normal, mostly wavy, and often damaged and necrotic at the tips; sometimes they were necrotic all over ... leaving a bare midrib. ... In some cases the attack resulted in a rot of the growing point, which ultimately killed the tree."

In both coconut and oil palms fairly large numbers of nematode, *Rh. cocophilus*, were found on discoloured tissues of young folded leaves. Living apparently ectoparasitically in the buds of the palms, the nematodes failed to produce symptoms characteristic of red-ring disease. They rarely occur on the white healthy parts of diseased young leaves, and never on the young leaves of trees that are free from little leaf. Inoculation experiments conducted by van Hoof and Seinhorst[29] by dropping a nematode suspension on the young leaves of five oil palms during wet season showed that one of them developed typical little leaf symptoms. From all these observations these authors concluded that the correlation between the occurrence of little leaf and the presence of *Rh. cocophilus* on the young leaves of coconut and oil palms is so close that this nematode can be suspected as being the cause of the disease. Malagutti's[30] observation that in a seven year-old palm plantation suffering from little leaf many trees had died apparently of red-ring disease is questionable in the light of new evidence as regards the symptoms, although the causative organism is the same. Little leaf associated with the presence of *Rh. cocophilus* on the young leaves was also found in British Guiana. Studies made by Hendriks and Glavimans[31], and van Hoof

and Seinhorst[29] in Surinam revealed no correlation between little leaf and the soil type.

***Rotylenchulus* sp.**

According to Corbett[32] 'Lethal yellowing' (unknown disease) also occurs in Florida on Key West. The symptoms of the disease as it occurs in Florida are more or less identical with those of Lethal yellowing prevalent in Jamaica and other countries. Recent investigations seemed to have ruled out the possibilities of mineral deficiency, nature of soil, insect pests, bacteria and fungi as the cause of the disease. Most of the research workers now appear to hold the view that the disease is of virus origin. Nematological research, probably initiated at the suggestion of Martyn[3], seems to throw much light on the aetiology of this disease as reported by Ollagnier and Weststeijn[2]. A new species of *Rotylenchulus* is present on an average in 38 per cent of samples from diseased trees. Examination of samples from healthy trees failed to show the presence of these worms. In Jamaica the same nematode has been found in 92 per cent of samples taken from the foot of diseased young trees, but only in 20 per cent of those collected from healthy trees. In the light of these findings, the State Board of Florida has already taken control measures with different nematicides and encouraging results seem to have been obtained with nemagon.

***Rotylenchus* sp.**

Fenwick and Maharaj[12] reported that roots of certain trees presumably suffering from red-ring disease, and showing symptoms such as drooping of bunches of nuts, and wilting and drooping of leaves in Trinidad showed many living specimens of *Rotylenchus* sp. instead of *Rh. cocophilus* (= *Aphelenchoides cocophilus*). The significance of this finding is not known. Although several species of *Rotylenchus* are parasitic on various plants, and economically important, data are lacking concerning their role in producing diseases of coconut palms.

Free-living Nematodes

***Metacrobeles togoensis* Loof (Rhabditida: Cephalobidae)**

Luc[33] has reported the presence of certain cephalobid nematodes associated with 'Kaincope disease' of coconut plams in Togo, Africa. Loof[34] studied these nematodes from a taxonomic point of view and found that they belong to a new genus of the Acrobelinae. He described them as *M. togoensis*. These nematodes are probably of no aetiological significance. No parasitic nematode seems to have been reported in relation to Kaincope disease.

***Panagrolaimus rigidus* (Rhabditida: Cephalobidae)**

This nematode has been found associated with wilting of coconut seedlings in Valiathura coconut nurseries, near Trivandrum, Kerala. Out of 7500 seedlings examined, more than 1700 showed the presence of the nematodes in large numbers in the root system (Antony, J., personal communication). While examining the young leaves of coconut palms suffering from root (wilt) disease, collected from Kavalam, Kerala, Nadakal[35] found fairly large populations of *Panagrolaimus* sp. in necrotic and semi-necrotic areas of the leaves, usually between the folds. Some parasitic fungi have also been noticed in the diseased leaves, one of which has been identified as *Helminthosporium* sp. Roots of diseased trees as well as the leaves and roots of healthy trees were found free of the nematodes.

Nematodes Involved in Fungus Diseases of Plants

Several species of nematodes are known to be associated with fungus diseases of plants, some of which are listed in Table 1. Pertinent literature on nematode-fungus interaction in producing disease complexes of plants has been recently reviewed by Powell[36]. The role of nematodes in such diseases is only imperfectly known. Newhall[37], Miller[38] and Slootweg[39], among others, believe that nematodes facilitate the invasion of the harmful fungi by mechanical wounding of plant roots. Investigators like Powell and Nusbaum[40], McKeen and Mountain[41], Thomason *et al.*[42], Schindler *et al.*[43] and Holdeman and Graham[44] maintain the opinion that there exists more complex relationship between the nematodes and fungi than simple mechanical wounding of the roots. Presenting all available evidence, they suggested that nematodes may either lower the natural resistance of host plants or cause physiological

TABLE 1 — SOME NEMATODES INVOLVED IN FUNGUS DISEASES OF PLANTS

Nematode	Fungus	Plant or disease	Ref.
Anguina tritici	*Dilophospora alopecuri*	Wheat	45
Belonolaimus gracilis	*Fusarium* sp.	Cotton wilt	44
Ditylenchus spp.	do	Carnation wilt	46
Heterodera rostochiensis	*Colletotrichum* sp.	'Potato sickness'	47
Hoplolaimus uniformis	*Fusarium oxysporum forma pisi* race 3	Early yellowing of peas	48
Meloidogyne incognita and *M. hapla*	*Rhizoctonia solani*	Soyabeans	49
	F. oxysporum f. *lycopersici*	Tomato wilt	50
M. incognita acrita	*R. solani*	Damping of cotton	51
	F. oxysporum var. *vasinfectum*; *Pythium debaryanum* *R. solani*	Cotton wilt	52
	Phytophthora parasitica var. *nicotianae*	Black shank of tobacco	53
M. javanica	*F. oxysporum* var. *tracheiphilum*	Cowpea wilt	42
Pratylenchus hamates	*Rhizoctonia* sp.	Stunting and chlorosis of celery	54
P. minyus	*R. solani*	Root-rot of wheat	55
P. penetrans	*Cylindrocarpon radicicola*	Root-rot of bulbs	39
Rhadopholus similis	*F. oxysporum* var. *cubense*	Banana wilt	37
Rotylenchulus reniformis	*Fusarium* sp.	Cotton wilt	56
Tylenchorhynchus claytoni	*F. oxysporum* var. *nicotianae*	Fusarium wilt of tobacco	57
Tylenchulus semipenetrans	*F. solani*	Citrus plant	58

TABLE 2 — NEMATODES INVOLVED IN BACTERIAL DISEASES OF PLANTS

Nematode	Bacteria	Host and disease	Remarks	Ref.
Anguina tritici	*Corynebacterium tritici*	Wheat-yellow slime	Parasites of aerial tissues	60
Aphelenchoides ritzemabosi	*C. fascians*	Strawberry-cauliflower	do	61
Ditylenchus dipsaci	*Erwinia rhaponticum*	Rhubarb-crown rot	do	62
Ditylenchus sp.	do	do	do	63
Helicotylenchus nannus	*Pseudomonas caryophylli*	Carnation wilt	Ectoparasites of roots	63
Meloidogyne incognita acrita	*P. solanacearum*	Tobacco-Granville wilt	Endoparasites of roots	64
Meloidogyne spp.	*P. caryophylli*	Carnation wilt	do	63
Tylenchorhynchus claytoni	*P. solanacearum*	Tobacco-Granville wilt	Ectoparasites of roots	65
Xiphinema diversicaudatum	*P. caryophylli*	Carnation wilt	do	63

changes favouring fungus invasion. Symptoms produced in plants are very often due to the synergistic action of both nematodes and fungi.

Nematodes Involved in Bacterial Diseases of Plants

Nematodes that are demonstrated to be associated with bacterial diseases of plants are listed in Table 2. Pitcher[59] has recently reviewed the literature on various aspects of nematode-bacterial interactions in producing disease complexes of plants. An important fact that has emerged from the reviewed literature is that relatively a small number of nematodes are known to be involved in bacterial diseases of plants. Although in nature virtually all nematodes are contaminated with bacteria and thereby act as vectors, the majority of the organisms carried by them are of little significance.

However, even some mildly virulent bacteria may take advantage of infection courts provided by nematodes producing a large number of local lesions. Although the part played by ectoparasitic nematodes in bacterial diseases is negligible, the endoparasites may aid the invasion of bacteria by providing avenues to inaccessible regions of host plants. Besides mechanical injury, nematodes may bring about physiological changes in host plants making them more susceptible to the attack of bacterial organisms. Studies of Pitcher[59] and Pitcher and Crosse[66] on cauliflower disease complex indicated that both the nematode and the bacterium contribute to the development of disease syndrome. It has also been observed by Pitcher[59] and Sabet[67] that in nematode-bacterium interactions, the latter exerts an inhibitory effect on the former in later stages of infection.

Nematodes Known to be Vectors of Microorganisms

Phytoparasitic Nematodes

As vectors of fungi — Atanasoff[45] reported that the nematode *Anguina* sp. acts as a vector for the fungus *Dilophospora alopecuri* which is responsible for a disease of wheat and certain other cereals in Europe. Spores of the fungus become attached to the nematode and are carried to the growing points and flower primordia of the plants.

As vectors of bacteria — The nematodes *Anguina tritici*, *Aphelenchoides ritzemabosi* and *Ditylenchus dipsaci* have been reported as essential vectors of pathogenic bacterial organisms (Table 2). The nematodes carry the bacteria from infected tissues on the same plant or from the soil to the vicinity of the apical meristem. Probably the nematodes also act as incitants.

TABLE 3 — NEMATODES SERVING AS VECTORS OF SOIL-BORNE PLANT VIRUSES

Nematode	Virus	Ref.
Longidorus elongatus	Tomato black-ring virus, beet ring-spot virus (TBRV-BRV)	68
	Raspberry ring-spot virus (RRV)	69
L. attenuatus	Tomato black-ring virus, lettuce ring-spot strain (TBRV-LRV)	68
Trichodorus pachydermus	Tobacco rattle virus (TRV)	70
T. primitivus	do	4
T. christiei	Potato corky ring-spot virus (TRV)	71
T. teres	Early browning virus of peas (PEBV)	72
T. viruliferus	do	73
Xiphinema index	Grapevine fanleaf virus (GFV)	74
	Grape yellow mosaic virus (CYMV) & Grape vein-banding virus (GVBV)	75
X. americanum	Tomato ring-spot virus-yellow bud mosaic strain (YBMV)	76
	Tobacco ring-spot virus of soya-beans (TRSV)	77
	Necrotic ring-spot virus of blue-berry (NRBV)	78
X. diversicaudatum	Arabis mosaic virus (AMV)	79-81

As vectors of soil-borne viruses of plant diseases — An excellent review on this subject has recently been made by Raski and Hewitt[4]. The known plant parasitic nematodes serving as vectors of plant viruses are presented in Table 3. They are all ectoparasitic aphasmid tylenchids belonging to three genera, *Xiphinema* and *Longidorus* of the family Dorylaimidae, and *Trichodorus* of the family Trichodoridae.

All stages of the nematodes, both adult and larvae, are capable of transmitting viruses. Evidence appears to be lacking as regards their transovarial transmission. According to Harrison and his associates[68] rod-shaped soil-borne viruses are vectored by species of the nematode genus *Trichodorus* and the globular viruses by species of *Xiphinema* and *Longidorus*. Harrison[82] has reported that soil-borne viruses

lose their infectivity when the soil is dried. Observations made by various investigators have provided evidence as to the persistence of viruses in the nematodes for variable periods of time. The grapevine fanleaf virus (GFV), for instance, can persist in its vector, *X. index*, for at least 30 days as reported by Raski and Hewitt[83]. Survival of viruses in the nematode vectors as long as 9 months has also been recorded by these authors[4].

Zooparasitic Nematodes

The association of nematodes and viruses has also been reported by various investigators in animal and human parasitology. A number of nematodes, which are known to transmit viruses of animal and human diseases, are presented in Table 4. In these cases, however, only the larval stages seem to be capable of virus transmission. The virus of swine influenza can survive as long as three years in lung worms encapsulated in earthworms, and it is thus perpetuated from one outbreak to another as reported by Shope[86,87]. It has been suggested by Chandler[89] that such virus diseases as poliomyelitis and ornithosis may be transmitted by eggs of intestinal worms like *Enterobius* spp. The role of zooparasitic nematodes, like that of phytoparasitic nematodes, as vectors of pathogenic viruses and other microorganisms remains mostly unknown. Zooparasitic nematodes involved in virus transmission belong to the class Secernentea (= Phasmidia) with the exception of *Trichinella spiralis* which is a member of the class Adenophorea (= Aphasmidia).

Some of the parasitic fungi reported by various workers in association with diseases of coconut palms are listed in Table 5. It is evident from Table 1 that some of these fungi such as *Fusarium*, *Rhizoctonia*, *Phytophthora*, *Thielaviopsis* and *Helminthosporium* are potentially capable of interacting with parasitic nematodes producing disease complexes. Insect pests have been considered to be a predisposing factor in fungus infections of coconut palms, particularly of aerial parts. Although recorded instances of disease complexes involving nematode and fungi appear to be lacking in the case of coconut palms, only future research can tell whether they do exist or not.

Available literature shows that our knowledge of parasitic nematodes associated with coconut palms is decidedly in an elementary state. *Rh. cocophilus* is the only nematode which is known to be of pathogenic significance and is undoubtedly one of the most intensively studied phytoparasites because of its economic importance. Red-ring disease which is attributed to this nematode, according to Oostenbrink[10], seriously limits the copra production in different regions of South and Central America, and also the yield of oil palms in Venezuela and other countries. A vast amount of information on various aspects of red-ring disease is now available particularly through the investigations of Fenwick and his associates[12-16,21,23,25]. Although red-ring is mainly restricted to South and Central American countries, its causative agent, *Rh. cocophilus*, appears to have been recorded in India by Thirumalachar[26] associated with bud-rot disease of areca palms. However, to the present author's knowledge, no information is available concerning its occurrence in coconut palms in India.

The demonstration by van Hoof and Seinhorst[29] that the same nematode, *Rh. cocophilus*, is responsible for little leaf is of considerable biological interest. Causation of two clinically different diseases by the same nematode in the same species of host plant is certainly intriguing. Usually restricted to the young leaves of trees, little leaf is apparently caused by the nematode ectoparasitically, whereas red-ring, which appears to affect any part of the tree, especially roots and stems, is produced by the nematode endoparasitically. Thus the same species of nematode acting as ecto- and endoparasite, and affecting obviously different parts of the host plant may have pathologically different manifestations resulting in little leaf and red-ring. It is possible that the nematodes responsible for these diseases may be morphologically indistinguishable but physiologically distinct. There are instances in animal parasitology as discussed by Chandler[89] in which two species of

TABLE 4 — NEMATODES KNOWN TO BE VECTORS OF VIRUSES OF ANIMAL AND HUMAN DISEASES

Nematode	Disease	Ref.
Ascaris suum	Infectious paralysis and virus pneumonia of pigs	84, 85
Metastrongylus sp.	Swine influenza	86, 87
Nippostrongylus muris	Virosis of rabbit	88
Strongylus sp.	Swamp fever of horses	89
Setaria digitata	Japanese B encephalitis	90
Toxocara canis	Virosis of mice	91
Trichinella spiralis	Lymphocytic choriomeningitis	92

TABLE 5 — A LIST OF PARASITIC FUNGI ASSOCIATED WITH DISEASES OF COCONUT PALMS

(Data from ref. 1)

Fungus	Disease	Countries
Botryodiplodia theobromae	Root (wilt) disease	Kerala
Botryodiplodia sp.	Leaf-break disease	Ceylon, Malaya, West Indies, etc.
Corticium penicillatum	Thread blight	New Guiana
Fomes spp.	'Root disease'	Ceylon
Fusarium oxysporum	?	Togo
Ganoderma lucidum	'Anabe roga'	India and Ceylon
Gliocladium roseum	Leaf-rot	Kerala
Glocosporium sp.	do	do
Helminthosporium halodes	do	do
H. incurvum	Leaf-spotting	Philippines
Macrophomina phaseoli	'Root disease'	Ceylon
Pestalotiopsis palmarum	Grey leaf-spot	Cosmopolitan
Phytophthora arecae	Bud-rot	India, West Indies, etc.
	Fruit-rot	Cosmopolitan
	Nut-fall or 'Mahali'	Kerala
Rhizoctonia bataticola	Root (wilt) disease	do
R. solani	do	do
Ceratostomella paradoxa	Bitten leaf; stem-bleeding	Jamaica; Ceylon, India, etc.

parasites, which are morphologically similar but physiologically distinct, produce clinically different diseases as exemplified by the parasitic protozoans, *Leishmania tropica* and *L. donovani*. The former affects the skin of human hosts and cause ' Oriental sore ' and the latter infects the visceral organs causing ' Visceral leishmaniasis ' or ' Kala-azar '. Here the species distinction appears to be based on ecological isolation and subsequent evolution up to physiological level. It may be said that the nematode involved in little leaf is a subspecies or a physiological strain of *Rh. cocophilus* with little or no morphological differentiation.

Nematological research in relation to coconut palms deserves more attention than what is given at present in view of the diverse ways in which these tiny worms can cause damage to host plants as described by Mountain[93]. They can be destructive to plants as pathogens as in the case of red-ring disease. Furthermore, they can serve as aggravators stimulating the growth of harmful microorganisms, or as incitants attacking fresh plant tissues and thereby providing infection courts for other organisms, or as vectors carrying a pathogen into host tissues. Oteifa[94] has shown that nematodes may also seriously interfere with the mineral nutrition of plant hosts. The role of phytoparasitic nematodes in disease complexes has been demonstrated in relation to a variety of host plants as shown in Tables 1 and 2. Similar data are, however, lacking as regards coconut palms. Several parasitic fungi capable of interacting with nematodes have been recorded from diseased coconut palms (Tables 1 and 5). Recently Lily[95] studied the parasitic fungi associated with root (wilt) disease of coconut palms in Kerala. Among several fungi observed, *Rhizoctonia solani* has been found to occur in higher frequency in the roots of affected palms than in those of healthy ones. The occurrence of free-living nematode, *Panagrolaimus* sp., in the young leaves of coconut palms afflicted with root (wilt) disease in Kerala is accompanied by various species of fungi, one of which is *Helminthosporium*. However, nothing is known as regards the nature of nematode-fungus interaction. Probably they represent simply a case of fortuitous association. Free-living nematodes such as rhabditids, diplogastrids, and others are often found in association with fungi and bacteria in plant lesions. It is doubtful whether they are capable of causing enough damage to initiate lesions, but as Christie[96] has pointed out that there is no reason why some of them may not be as important in extending the injury as are other secondary invaders. Again, according to Seinhorst[97] rhabditid species, which normally feed on bacteria, sometimes ' nibble ' at root hairs or at young tissues in buds and damage plants by devouring bits of tissues.

The potential danger of nematodes serving as vectors of soil-borne viruses of plant diseases, as demonstrated recently by various workers in relation to a variety of plants, opens up a new field of nematological research. The techniques and methods developed in relation to the study of plant viruses vectored by nematodes have been reviewed by Raski and Hewitt[4]. As root (wilt) disease of Kerala, Cadang-cadang of Philippines, and Lethal yellowing of Trinidad, Jamaica and other countries are suspected to be of virus origin, research may be organized in an effort to find a soil organism which might serve as vector of soil-borne viruses. The report of the occurrence of the nematode, *Rotylenchulus* sp., associated with coconut palms suffering from Lethal yellowing in Florida and Jamaica by Ollagnier and Weststeijn[2] provides an important lead for research in this line. Control measures adopted for this disease by the application of nematicides like nemagon have yielded encouraging results. There is little doubt that species of *Xiphinema*, *Longidorus* and *Trichodorus*, which have been proved to be vectors of soil-borne viruses in other countries, should also occur in India as suggested in the recent report of Swarup *et al.*[98].

It is doubtful whether free-living nematodes can serve as vectors of soil-borne viruses. Recorded instances of virus diseases of plants are vectored by ectoparasitic nematodes belonging to the class Adenophorea. However, zooparasitic nematodes (Table 4) which serve as vectors of viruses of animal diseases belong to both classes Adenophorea and Secernentea. The morphological or physiological adaptations which qualify them for the role of vectors of viruses remain to be elucidated. Discounting the slim possibility that the free-living nematodes may act as vectors of soil-borne viruses of plant diseases, it would be desirable to make an assessment of the role of *Panagrolaimus* sp. and *Metacrobeles togoensis* in the aetiology of the diseases with which they are associated.

The part played by intercrops or weeds in the spread of parasitic organisms such as nematodes, bacteria, fungi and viruses from palm to palm is to be investigated. Attention has been drawn to this fact by Holmes[99] in connection with the aetiology of Cadang-cadang of Philippines. This disease seems to involve extremely complex interactions of weed hosts and insect vectors. Studies of Lily have revealed that populations of *Rhizoctonia solani* and other fungi associated with root (wilt) disease are shared by the intercrops such as *Vigna sinensis*, *Cajanus indicus*, *Crotalaria juncea* and *Arachis hypogaea*. Nadakal[100] has shown that many of the intercrops and weeds that usually grow in coconut gardens are highly susceptible to the attack of root-knot nematodes which often act as incitants for the colonization of harmful microorganisms. Spread of harmful soil organism can also take place from tree to tree via root system where the roots of adjacent trees intermingle as reported by Fenwick and Maharaj[12] in the case of red-ring nematode, *Rh. cocophilus*. Observations of Lister[101] and Cadman and Lister[102] indicate that such viruses as TRV, AMV and TBRV, all of which have ectoparasitic nematodes as vectors, may be carried by seeds of infected crops or weed hosts. According to Holmes[99] Cadang-cadang disease of coconut palms in Philippines spreads rapidly from island to island probably because of the scattering of seeds of weeds by seed-eating birds or passive transportation of such seeds by man. The rapidity with which Cadang-cadang, root (wilt) and Lethal yellowing diseases spread from tree to tree would suggest a virus aetiology and one may be tempted to postulate that

the virus pathogen may also spread as droplet infection through specks of organic materials as are certain viruses of animal and human diseases.

Rh. cocophilus, the causative organism of red-ring, and apparently of little leaf of coconut and oil palms, is known to be vectored by the palm weevil, *Rh. palmarum* L. A related species, *Rh. ferrugineus* F., occurs in Kerala and is a serious pest of coconut palms. However, information appears to be lacking as regards the nematodes parasitic or saprophagous, harboured by this insect. A search for nematodes occurring in insect pests of coconut palms such as *Oryctes rhinoceros* L., *Nephantis serinopa* Meyr., *Stephanitis typicus*, *Rh. ferrugineus*, etc., would be highly rewarding particularly in view of the importance of nematodes serving as vectors of viruses. The recent report by Shanta *et al.*[103] that the insect, *Stephanitis typicus*, can act as a vector of the virus of Kerala-wilt suggests an alternative possibility of the insect pests transmitting viruliferous nematodes from tree to tree.

Summary

Parasitic nematodes known to be associated with diseases of coconut palms are decidedly small in number. The red-ring nematode, *Rh. cocophilus*, is the most important parasite that has been studied extensively by various workers. A wealth of information concerning the aetiology, epidemiology, pathology, symptomatology and prophylaxis of red-ring disease is now available. The palm weevil, *Rh. palmarum*, serves as a vector of *Rh. cocophilus* both in the case of red-ring and little leaf diseases of coconut and oil palms in South and Central American countries. The observation that the same species of nematode, *Rh. cocophilus*, is responsible for two clinically different diseases in coconut and oil palms is of considerable biological interest. It is possible that these nematodes, although morphologically indistinguishable, may be physiologically distinct strains of the same species. The other parasitic nematodes recorded from coconut palms are *Rotylenchus* sp. and *Rotylenchulus* sp., the former associated with red-ring and the latter with Lethal yellowing in Florida and Jamaica. The nematode *Rotylenchulus* appears to be involved in the Lethal yellowing of the palms since control of this disease by the application of nematicides like nemagon seems to yield promising results. Free-living nematodes, *Panagrolaimus* sp. and *Metacrobeles togoensis*, have been detected in association with root (wilt) disease in Kerala, and Kaincope disease in Togo, Africa, respectively. The role of phytoparasitic nematodes involved in various plant disease complexes has been discussed in relation to bacteria and fungi. The potential danger of certain species of nematodes serving as vectors of soil-borne viruses of plant diseases has been discussed providing lists of known phyto- and zooparasitic nematodes involved in virus transmission. A discussion has been made of the possible role of intercrops, weeds and insect pests in the spread of harmful microorganisms among the coconut palms indicating the possibility of the insemination of viruliferous nematodes by them. In view of the multiplicity of ways in which nematodes play an important role in our agricultural economy, there is now an imperative need for organizing nematological research in relation to coconut palms at ecological, biological and aetiological levels. A survey of disease-stricken coconut gardens including their soils, intercrops, weeds, insect pests as well as different parts of coconut trees themselves for nematode population is likely to yield promising results.

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REVIEWS

THE PLANET EARTH edited by D. R. Bates (Pergamon Press Ltd, Oxford), 1964. Pp. vii+370. Price 42s.

The first edition of this work containing a series of articles by leading authorities in geophysics appeared in 1957. The articles have been revised for this edition. An extra article on the Van Allen radiation belts, which were discovered soon after the first edition was published, has been included.

The book contains 18 articles which cover a wide range of topics. The introductory paper is by Sidney Chapman on the International Geophysical Year and its achievements. Gerard Kuiper traces the history of the earth and its possible future which is bound up with the development of the sun. The third paper by Bullen deals with the interior of the earth and its investigation by seismic waves. It is now agreed that the earth's core consists of two parts, the outer fluid and the inner solid. The latest data seem to indicate that the centre of the earth has a density of around 15, instead of a range of 14-18. The Chilean earthquake of 1960 has given information on the free oscillations of the earth, of which more than 40 separate periods between 3 and 60 min. have been recorded.

The next paper is on the development and structure of the crust by Tuzo Wilson. He shows that there are four stages in mountain growth, exemplified by the mountains of the Aleutian arc, British Columbia coast, Appallachians and Grenville province, from the youngest to the oldest. The latest information on tides, waves, currents and water masses are presented briefly in a paper on the ocean by G. E. R. Deacon. Vestine deals with the geomagnetic field, the secular changes connected with it and recent work on remanent magnetism. The next contribution by D. R. Bates deals with the structure and the composition of the atmosphere. Intensive studies are being made on the outermost layers (exosphere) which at a height of 300 miles has a pressure of only 10^{-12} of one atmosphere. It is calculated that about 10 tons of hydrogen are lost everyday into space and that at very great heights hydrogen is the dominant constituent, followed by helium.

The contribution by E. T. Eady deals with climate and the general circulation of atmosphere and the oceans. Ice ages are considered by Opik who states that three major glaciations are known since the beginning of the Cambrian and five more before that date. He is of the opinion that mountain building and geographic altitudes cannot explain ice ages and that there must be other causes. He also considers that palaeomagnetic data and the former distribution of animals and plants do not support continental drift. A short description of ice cap of Greenland is given and figures are quoted to show that the amount of ice during Pleistocene amounted to 3·3 times the volumes of the present amount of 4·86 cubic miles. He favours the variations of solar radiation as the cause of ice ages.

B. J. Mason has an article on meteorology; J. A. Ratcliffe on the ionosphere and its properties; and D. R. Bates on air-glow. In recent years the green lines in aurorae have been proved to be due to atomic oxygen. The sodium doublet occurs in the visible regions while Lyman alpha line due to atomic hydrogen and infrared band due to OH have also been confirmed. The OH, D and green lines appear in aurorae at 55-60 miles altitude, while the red lines and Lyman alpha lines appear at 150 miles. V. C. A. Ferraro considers the connection of aurorae with magnetic fields. A. C. B. Lovell describes the nature of meteorites and meteors which are now studied with the help of radio telescopes. It is now known that over a million tons of very fine meteor dust (micrometeorites) fall on the earth every year. Some of the huge falls which have produced craters and devastation of large areas also find a mention.

J. G. Wilson in his paper describes the production and the nature of the cosmic rays. The Van Allen belts of radiation are described by J. W. Dungey. Discovered in 1958, they are known to extend 500-10,000 miles in space from the earth. They are essentially magnetic fields in which the particles (protons and electrons) perform spiral motions but are kept within the belts.

The last article is by J. B. S. Haldane on the genesis of life. He suggests that anaerobic metabolic processes generally found in all organisms are more primitive than aerobic ones, and that the first organism broke down metastable compounds in a medium containing a little molecular oxygen. When enzymes and suitable substrates are available DNA molecules can be accurately copied and reproduced. After many million years during which the atmosphere contained only a trace of oxygen, life began to multiply when much of the hydrogen had been lost and photosynthesis became effective, producing oxygen. There must be millions of planets supporting life as we know it and perhaps as many others which support life in ammonia medium.

The book is an excellent introduction to many aspects of geophysics and provides an authoritative and accurate picture of the present state of knowledge of the earth, the oceans and atmosphere. It is well got-up and printed and will repay study by all who are interested in modern geophysics.

M. S. KRISHNAN

HIGH TEMPERATURES IN AERONAUTICS — International Series of Monographs in Aeronautics and Astronautics: Vol. 15, 1964. Pp. xiii+446. Price £5 5s.

The volume under review records the proceedings of a symposium held in Turin to celebrate the 50th anniversary of the 'Laboratorio di Aeronautica' and contains 18 papers dealing with different aspects of high temperature phenomena in aeronautics. Broadly speaking, the articles in the volume may be classified under the following three headings:

(i) Hypersonic flow and magneto-fluid mechanics, (ii) Radiation gas dynamics, and (iii) Materials.

When a body is moving in a gas at hypersonic velocities, very high temperatures are produced in front of the shock which result in the dissociation of the molecules into their constituent atoms and even ionization of the gas. The modifications in the flow brought about by the chemical reaction and ionization effects are discussed in the first two papers of the volume. Another chemical problem, which has attracted the attention of both the experimenters and theorists, concerns the combustion in a stream which moves at supersonic velocity. One of the practical motivations for research on this problem is the hypersonic ramjet using supersonic combustion. In the paper entitled 'Theoretical and experimental investigations of supersonic combustion', Ferri, Libby and Zakkay give the results of their theoretical and experimental investigations of supersonic combustion. After reviewing briefly the present state of the subject, these authors give an analysis of (a) inviscid flow fields with a finite rate chemistry for a hydrogen air reaction and (b) turbulent mixing for flows with large density gradients. In an interesting paper entitled 'Non-equilibrium flow through a nozzle', P. A. Blythe examines the vibrationally relaxing flow through a nozzle for the case when the amount of energy in the lagging mode is small. The author shows that there exists a 'boundary layer' region in which relatively large departures from equilibrium occur.

With the advent of new developments in space science and technology, the scope of activity covered by the aerodynamicist has broadened enormously during the last decade. Developments in chemical propulsion techniques have led to the introduction of large sections of chemical kinetics into combustion theory and propulsion applications, and similarly the prospect of space flight applications using low thrust devices for interplanetary manoeuvres has turned the attention of many aerodynamicists to basic and applied problems in magnetohydrodynamics. Yet another discipline, which is becoming of increasing importance to the aerodynamicist, is the spectroscopy of hot gases. This subject, which till recently was studied mainly by astrophysicists, forms the basis for a quantitative understanding of radiative transfer problems in hypersonic flight and in chemical or nuclear-powered rocket engines. The volume contains several papers which deal with radiative transfer studies for heated gases, similarity parameters in radiation gas dynamics and photoionization upstream of a strong shock wave. The last few papers of the book deal with the material problems at high temperatures. There is an interesting review of the properties of silicon nitride, which owes its importance in aeronautics to its high thermal shock and high heat resistance properties.

What strikes conspicuously the reader is the picture the book gives of the new trend in fluid mechanics which has been shaped by the constant impact of the surging waves of new ideas in physics and chemistry. The book is, without doubt, a valuable addition to the literature on aeronautics and astronautics.

S. P. VENKITESHWARAN

AGARDOGRAPH 77 — MICROPOWER ELECTRONICS edited by Edward Keonjian (Pergamon Press Ltd, Oxford), 1964. Pp. vii+216. Price 84*s*.

The book is a collection of eight lectures delivered during the Avionics panel meeting of the AGARD on the general subject of reducing power dissipation in microelectronic devices. The lectures were organized by the editor to discuss some of the latest developments on microminiaturized equipment which has much higher power density than conventional circuits and has sufficiently high reliability. They are published in a book form to contribute towards a better understanding on the operation of electronic units at micropower levels.

Each lecture is given in a separate chapter and the discussion of the panel on each topic is given in the last chapter. The first chapter is on the relation between minimum required power density and frequency response for present and future semiconductor triode amplifiers by Prof. J. L. Moll of Stanford University, where the author discusses the application of bipolar transistors and field effect transistors in high frequency amplifiers and fast switches. The second paper by Prof. A. W. Lo of Princeton University on physical realization of digital logic circuits is devoted to micropower operation for digital information processing systems. The author has presented a unified concept of the requirements of physical realization of elementary digital networks and discusses in detail the direct coupled transistor logic circuit and the transistor diode logic circuit. The third paper on metal-oxide-semiconductor field effect devices for micropower logic circuitry by G. E. Moore and associates of Fairchild Semiconductor Corp. discusses logic circuits for digital applications, based upon complementary polarity metal-oxide-semiconductor field effect transistors, which operate at very low supply power and high switching speed. Considerable saving of power is achieved since no power is required to maintain the circuit in binary state and energy is dissipated only while being switched. The fourth paper on micropower microelectronic subsystems by W. W. Gaertner and associates of CBS Laboratories describes recent microelectronic concepts which stress on the performance with minimum supply power level and high reliability. Construction techniques for an amplifier, counter and a shift register and the details of an analogue to digital converter with a conversion rate of 20 μsec. per bit are described. The fifth paper on a microminiature digital integrator using micropower circuits by A. T. Watta describes a digital integrator, made to prove the practicability and performance of system built from thin film microcircuits. The sixth paper by B. A. Boulter deals with multiple emitter transistor in low power circuits, discussing the relative merits of this silicon planar device. In the seventh paper on designing minimum power digital circuits for Mariner II and other spacecrafts R. C. Baron discusses the special features encountered in the design of a digital data handling system where ultra reliability, minimum power, weight and volume are vital. The main circuits in the system are for controlled sampling of experiments, preparation of data for transmission and generation of control and calibration signals. The last paper on static and dynamic performance of

micropower transistor linear amplifiers by J. N. Miendl and associates discusses optimum design and performance characteristics of linear broad band amplifiers using silicon planar transistors which have very low reverse currents.

The text has been profusely illustrated and each chapter is complete with a bibliography of the recent literature on the subject. The broad spectrum of the problem of micropower electronics, supplemented by valuable comments, gives a lucid picture of the state of art and helps the engineer to visualize a new field in electronics, which holds promise for a more efficient and reliable equipment. The book is a valuable addition to an electronics library.

C. S. RANGAN

JAPANESE MINIATURE ELECTRONIC COMPONENTS AND ASSEMBLIES DATA ANNUAL edited by G. W. A. Dummer & J. Mackenzie Robertson (Pergamon Press Ltd, Oxford), 1964. Pp. xxiii+483. Price £ 7

This volume is published as an electronic component data annual series by the Pergamon Press. The authors have given a comprehensive information on the various small size radio components and assemblies, manufactured by the Japanese electronic industry. The text is actually a manual comprising a large number of technical catalogues and data sheets published by such leading manufacturers as Messrs Fujitsu, Matsushita and Nippon companies. Some of the main components for which exhaustive details are given are fixed and variable resistors and capacitors, miniature ceramic and electrolytic capacitors, RF and IF coils for radio receivers, plugs, sockets and switches. Assembly components such as printed circuit boards, micro-assembled circuits and semiconductor integrated logic circuits are also included. Basic design features of circuits with the technical specifications and application data are given in many cases to help the designer. A list showing the title and number of standard specifications for the different components published in Japan is also furnished.

The book is profusely illustrated, showing component dimensions and actual photographs. It is very instructive especially to those who wish to acquire a knowledge of miniature electronic products available from Japanese sources.

C. S. RANGAN

RADIATION PROTECTION: RECOMMENDATIONS OF THE INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION — ICRP Publication 4 (Pergamon Press Ltd, Oxford), 1964. Pp. v+70.

The widespread applications of radiation sources such as radioactive isotopes, research reactors, X-ray machines and particle accelerators require competent guidance for the protection of persons handling these sources. As far back as 1928 when the scale of handling of radiation sources was negligible compared to that in the modern times, a Commission was established at the Second International Congress of Radiology under the name of International Commission on X-ray and Radium Protection which was renamed in 1950 as the International Commission on Radiological Protection. This Commission, abbreviated as ICRP, was established to give recommendations on the safety aspects of ionizing radiations.

Since its creation in 1928 the Commission has kept its recommendations continually under review in the light of new knowledge concerning the effects of atomic radiation. It has published, since 1958, a series of 6 reports (known as ICRP Publications) relating to permissible dose for internal radiation, protection against X-rays, handling and disposal of radioactive materials and other allied topics.

In its latest form the Commission consists of 12 members with 4 committees working for it, designated as Committee 1, 2, 3 and 4, to deal with radiation effects, internal exposure, external exposure and application of recommendation respectively. The report under review is a report of Committee 4 which was one of the six committees of the ICRP which existed up to May 1962, when the Commission was reorganized in its present form. This report deals with ' Protection against electromagnetic radiations above 3 MeV. and electrons, neutrons and protons '. The risks and the special problems involved in the use of radiations at high energies are of a special nature and require specific recommendations, different from those given for the radiations at low energy. These recommendations are important because of the widespread use of modern machines for the acceleration of electrons and heavier particles to high energies now extensively used for research in physics all over the world. The report gives a summary of the recommendations for different types of high energy machines used in medicine, industry and research. The concept of linear energy transfer, the understanding of which is vital for the protection against high energy radiation, has been explained in an appendix. The absorption data for electromagnetic radiation and dose build-up factors are also given in the appendices and a prefatory review of the recommendations of the ICRP prepared in 1958 and its revision up to 1962 are given at the end of this report. The report would prove valuable to the health physicists responsible for radiation monitoring for particle accelerators, to the engineers responsible for the design and installation of accelerators, and to the physicists and engineers working with these high energy machines.

K. G. VOHRA

RECOMMENDATIONS OF THE INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION — ICRP Publication 6 (Pergamon Press Ltd, Oxford), 1964. Pp. v+44

The understanding of harmful effects of atomic radiations requires a long-term study of the problem. The International Commission on Radiological Protection, which was first formed in 1928 under the name of International X-ray and Radium Protection Commission, has been continuously working on the standards of radiation protection, and has been issuing its recommendations from time to time. The first report of the Commission in the present series was published in 1958 under the title ' Recommendations of the International Commission on Radiological Protection ' — ICRP Publication 1. These recommendations were amended in 1959, and further revised in 1962. The publication under

review bears the same title as the 1958 report, and is issued as ICRP Publication 6. ICRP Publications 2, 3, 4 and 5 are the reports of the different committees dealing with specific topics in radiation protection such as internal exposure, external exposure and waste disposal. The present publication incorporates all the amendments in the 1958 report made up to May 1962, and is the latest published document of the Commission. This publication contains the explanatory statements to be incorporated in the earlier recommendations. It also gives all the Commission's general recommendations, as amended to 1962. The amendments consist of, mainly, the definition of ' Quality factor ' which replaces RBE used earlier for the purpose of dose evaluation in radiation protection; the current views of the ICRP on the lens of the eyes as ' critical organ ', definition of permissible dose, dose-rate effects, exposure of women of reproductive age, emergency exposure, maximum permissible concentrations of strontium-90 in water and air, and maximum permissible concentrations of radon-222 in the air.

In the past a linear dose-effect relationship has been accepted for gene-mutations, unaffected by dose-rate. Although the Commission has noted recent investigations on non-linearity of the dose-effect relationship at higher dose-rates, it has not yet modified its recommendations to allow for dose-rate effects in man. For somatic effects the report suggests a linear dose-rate relationship for very low dose-rates, but it makes no mention of dose-rate effects at higher dose-rates for somatic effects.

The values of ' maximum permissible dose ' continue to be the same as recommended in the 1958 report except for a few explanatory notes. However, the Commission has now recommended that 13-week dose to the women of reproductive age be limited to 1·3 rems in a 13-week period for occupational exposure and the total dose should not exceed 1 rem during the period of pregnancy. The Commission has also given useful recommendations regarding radiological examinations of women of reproductive age. However, the Commission has not made any numerical recommendation with regard to the appropriate genetic dose from medical exposure.

The publication includes in Part 2 the details of the organization of the Commission. Part 3 gives the explanatory statements for the amendments to the 1958 recommendations. Part 4 contains all the Commission's general recommendations as amended to 1962. Parts 5 and 6 contain 1962 supplement to ICRP Publication 2 and 1962 addendum to ICRP Publication 3. This publication and all the preceding publications of the Commission are very valuable documents in the field of radiation protection and it is desirable that the Commission now publishes its complete recommendations as a single document.

K. G. VOHRA

THE NUCLEOHISTONES edited by J. Bonner & Paul Ts'O (Holden-Dey Inc., San Francisco), 1964. Pp. xiii+398. Price $ 12.75

The book is the outcome of the first world conference on histone biology and chemistry held from 29 April to 2 May 1963 at Rancho Santa Fe, California, under the auspices of the Division of Biology, California Institute of Technology. The conference was attended by 56 scientists who are actively engaged in research on various aspects of nucleohistones. A total of 39 papers were presented and they are grouped in 7 chapters in this book.

The first chapter consists of a single paper on the pioneers of histone chemistry and describes the discovery of nucleohistones by Miescher followed by works of Kossel. This is only of historical interest and does not add much to the quality of the book. The next chapter on histone chemistry indicates the great strides that have been made to isolate and characterize the various fractions of histones from various sources. It is confirmed that histones are very heterogeneous and there could be hundreds of different kinds of molecules of histones. The chapter on structure of nucleohistones gives some new ideas on how histones could be associated with DNA. In addition the older idea that histones are wrapped round the grooves of DNA molecule, Zubay has proposed that the histones run at an acute angle to DNA molecules. This bears implications on the chromosome structure. Richards has proposed that histones are located between pairs of DNA molecules.

The fourth chapter deals with histone metabolism and chromosome structure. Cytochemical studies of Swift indicates that histones are chiefly involved in chromosome structure rather than in genetic suppression. Prescott claims that nuclear protein shows dispersive distribution on mitosis. Flamm and Birnstiel question that histone synthesis is obligatorily linked with DNA synthesis. These workers and Busch and coworkers contend that nucleolus is the major site of histone synthesis. The fifth chapter, dealing with enzymology related to the nucleohistones, reaffirms the concept that DNA-dependent RNA synthesis is inhibited by histones and in *in vivo* systems even DNA synthesis is strongly repressed by histones. The role of histones in development is dealt with in the next chapter. In addition to the works on puffing of polythene chromosomes, the role of steroid hormones in activating genes is illuminating. The seventh and the final chapter entitled 'Thoughts for the future' is very exhilarating. A number of authors have discussed the present state of knowledge and have pointed out various specific problems that need critical investigation.

This book is better than a typical symposium volume. It is more than an ensemble of papers and presents an integrated picture of the specific field. The idea of having a chapter like ' Thoughts for the future ' is worth emulating. Undoubtedly the book would be helpful and stimulating to the students and research workers interested in modern biology.

DEEPESH N. DE

AN ANTHOLOGY OF FOOD SCIENCE: Vol. 2 — MILESTONES IN NUTRITION by Samuel A. Goldblith & Maynard A. Joslyn (AVI Publishing Co. Inc., Westport, Connecticut), 1964. Pp. xv+797. Price $ 15.25

This book is an anthology of the science of nutrition. It not only makes interesting reading but also gives much useful information to a student of nutrition; especially, it gives the reader an insight into how nutrition has developed into a specific field of science.

The first paper in the book, ' A history of metabolism ', by Grahan Lusk deals with the history of medicine and nutrition. This paper helps one to know the contribution chemists have made towards the development of medicine and nutrition and also the close interrelation that exists between these branches of science.

The greater part of the book is devoted to the field of vitamins. These papers deal with the problems that were encountered in the treatment and prevention of these deficiency diseases; the difficulties that were encountered in the discovery of vitamins and of their role in nutrition. This part of the book covers papers on the fat-soluble vitamins A and D; beriberi and vitamin B_1; pellagra; scurvy and vitamin C. Chapter 11 includes work on pyridoxine by Samuel Lepkovsky, to whom this book is dedicated.

The other papers in this anthology are about amino acids, proteins and minerals. The chapter on amino acids and proteins contains papers by three of the most important investigators in the field of amino acid nutrition — Osborne, Mendel and Rose. These papers deal with the role of indispensable amino acids and of amino acid imbalance in nutrition.

One feels, however, that the chapter on ' Minerals ' is very inadequate. Both the papers that have been included are on ' Iron in nutrition '. No paper on any other mineral has been included. Considering the fact that much of the book is devoted to vitamins, it would have been better if the editors had included papers dealing with the role of calcium in nutrition and its interrelation with vitamin D.

The book would have been more complete if work on lipids and carbohydrates had also been included. Considering the fact that metabolic disorders like atherosclerosis and diabetes are now problems of the nutritionist, it is surprising that these two aspects have been completely excluded.

A commendable feature of the book is that at the beginning of each chapter, photographs and short life sketches of some of the eminent scientists are presented.

This is a book which every student of nutrition should read.

C. GOPALAN

AN INTRODUCTION TO FEEDING FARM LIVESTOCK by Robert H. Nelson (Pergamon Press Ltd, Oxford), 1964. Pp. 108. Price 17*s*. 6*d*..

This is an excellent book for beginners in animal husbandry course. The subject matter of livestock feeding has been dealt with in a lucid manner, which will be easily understood by young people, starting on agricultural, dairying or animal husbandry course. However, a few additions and alterations are suggested which, according to this reviewer, will enhance the value of this book.

In Chapter 2 (p. 13), it will be of practical importance to mention that non-sweating animals like cattle can remove a good portion of their surplus heat through evaporation of water from lungs (respiration). As such, these animals adapt themselves to higher environmental temperature in summer by increasing their respiratory rate.

In Chapter 3, lignin has been classified as a carbohydrate. This is not correct. In page 16, it has been mentioned that as plants mature, they lose their feeding value. A more correct description will be that ' as plants mature, their feeding value is diminished '.

In Chapter 4, the role played by fats in energy supply to the body needs elaboration.

In Chapter 7, vitamin B_{12} has not been mentioned. In view of its importance in poultry and pig rations, a short description of this vitamin will be useful.

In Chapter 8 (p. 42), propionic acid should be added to acetic and butyric acids.

There is an obvious mistake in Chapter 10 (p. 61). For measuring digestibility of feed protein, analysis of urine is not required. Urinary nitrogen content is to be determined only to find out the balance of nitrogen in an animal.

It is surprising that no ration schedules for poultry have been included in the book. One more chapter on this subject is sure to add to the usefulness of this type of text-book.

S. N. RAY

THE ECOLOGY OF WASTE WATER TREATMENT by H. A. Hawkes (Pergamon Press Ltd, Oxford), 1963. Pp. ix+203. Price 42*s*.

The aim of this book, as stated by the author in the preface, is " to provide some understanding of the biological aspects of waste water treatment for the non-biologist employed in this field ". The modern biological methods of treatment of waste waters, such as bacteria beds and activated sludge plants, are designed, constructed and operated by engineers and chemists who, " in many cases, have little or no biological training ". For them and others concerned with the prevention of river pollution, a knowledge of the basic biological principles of waste water treatment, the interrelationships of populations of the necessary organisms and their environment should be useful.

The first chapter of the book deals with those basic principles of biology considered necessary for an understanding of the following six chapters in which the dominant organisms present notably in bacteria beds and activated sludge are first enumerated and then the factors influencing their numbers and activity are considered, and finally the practical application of these factors or principles to plant design and operation is discussed. Three of these chapters contain the results of the author's own investigations on the ecology of bacteria beds. The diagrams are good.

In formulating a theory as a working hypothesis for the correlation of experimental evidence and operational experience, particularly for the mechanism of the removal of organic matter from waste waters by activated sludge, the author has endeavoured to give a generally balanced view of the present state of our knowledge. At the same time he makes a cautious and comforting statement, which is of more general interest: " One must, however, be willing to change or modify a theory to accommodate any new and valid evidence or experience, one's sense of judgement being consoled by the thought that in science there is no such thing as the ultimate truth ! " (p. 126).

The book is well produced, and it should be of real assistance to those for whom it is primarily intended.

S. C. PILLAI

BOOK NOTE

ELECTRONIC PROPERTIES OF MATERIALS: A GUIDE TO THE LITERATURE edited by H. Thayne Johnson (Plenum Press Inc., New York), 1965. Pp. 2000 (approx.). Price $ 150

This two-volume work is a major contribution towards solving the increasingly large problem of information retrieval in this field and has been designed to function as a critical and convenient guide to sources of experimental data on electrical and electronic properties of nearly 10,000 materials. The compilation has been made after a selective literature search by a group of six scientists of the Electronic Properties Information Centre (EPIC), an organization set up by the Hughes Aircraft Co. to collect, index and abstract literature on the electrical and electronic properties of materials and to evaluate and compile the experimental data from over 5,00,000 publications, growing at the rate of 5000 per month. The guide covers the nine major categories of materials, viz. semiconductors, insulators, ferroelectric dielectrics, metals, ferrites, ferromagnetics, electroluminescent materials, thermionic emitters, and superconductors and is bound to be a valuable reference book for all engineers and scientists concerned with the application of these materials.

PUBLICATIONS RECEIVED

PRINCIPLES OF ATOMIC ORBITALS by N. N. Greenwood (Royal Institute of Chemistry, London), 1964. Pp. 46. Price 6*s*.

ALGAE AND MAN edited by Daniel F. Jackson (Plenum Press Inc., New York), 1964. Pp. x+434. Price $ 14.50

KUNSTLICHE ORGANISCHE FARBSTOFFE UND IHRE ZWISCHENPRODUKTE by H. R. Schoveizer (Springer & Verlag), 1964. Pp. xii+542. Price DM 49.60

NEUTRON IRRADIATION AND ACTIVATION ANALYSIS by Denis Taylor (George Newnes, London), 1964. Pp. ix+185. Price 50*s*.

A SYSTEMATIC CLASSIFICATION OF TYPES OF INTERMETALLIC STRUCTURES; translation from the Russian; reprinted from *J. struct. Chem.*, **4** (1963) by P. I. Kripyakevich (Consultants Bureau Enterprises Inc., New York), 1964. Pp. 35. Price $ 10

BIOCHEMISTRY OF THE BRAIN DURING THE PROCESS OF DYING AND RESUSCITATION by Mariya Sergeevna Gaevskaya; translated from the Russian by J. A. Stekol (Consultants Bureau Enterprises Inc., New York), 1964. Pp. 101. Price $ 17.50

THE CUBE MADE INTERESTING: Vol. 9, by Aniela Ehrenfeucht; translated from the Polish by Waclaw Zawadowski (Pergamon Press Ltd, Oxford), 1964. Pp. vii+83

RECENT PUBLICATIONS

Mathematics

ADVANCES IN MATHEMATICS: Vol. I, edited by H. Busemann (Academic Press Inc., New York), 1964. Pp. 162. Price $ 5.50

Physics

MAGNETISM — A TREATISE ON MODERN THEORY AND MATERIALS: Vol. 2A, edited by G. T. Rado & H. Suhl (Academic Press Inc., New York), 1964. Pp. 430

ADVANCES IN RADIO RESEARCH: Vols. 1 & 2, edited by J. A. Saxton (Academic Press Inc., New York), 1964. Vol. 1: Pp. 266. Price $ 8.50. Vol. 2: Pp. 215. Price $ 8.50

THE DIRECT OBSERVATION OF DISLOCATIONS by S. Amelinckx (Academic Press Inc., New York), 1964. Pp. 487. Price $ 17.00

POTENTIAL BARRIERS IN SEMICONDUCTORS by B. R. Gossick (Academic Press Inc., New York), 1964. Pp. 160. Price $ 2.45 (paper bound); $ 5.50 (cloth bound)

CONCEPTS IN QUANTUM MECHANICS by F. A. Kaempffer (Academic Press Inc., New York), 1964. Pp. 360. Price $ 12.50

PHYSICAL ACOUSTICS: PRINCIPLES AND METHODS — Vol. 2, Part A, edited by W. P. Mason (Academic Press Inc., New York), 1964. Pp. 445

STATISTICAL THEORIES OF SPECTRA — FLUCTUATIONS by Charles E. Porter (Academic Press Inc., New York), 1964. Pp. 575. Price $ 19.50

INTERPRETATION OF METALLOGRAPHIC STRUCTURES by W. Rostoker & J. R. Dvorak (Academic Press Inc., New York), 1964. Pp. 220. Price $ 7.50

MOSSBAUER EFFECT: PRINCIPLES AND APPLICATIONS by Gunther K. Wertheim (Academic Press Inc., New York), 1964. Pp. 116. Price $ 2.45 (paper bound); $ 5.50 (cloth bound)

OPTICAL PROPERTIES OF MINERALS: A DETERMINATIVE TABLE by Horace Winchell (Academic Press Inc., New York), 1964. Pp. 125

Chemistry

ADVANCES IN QUANTUM CHEMISTRY: Vol. 1, edited by Per-Ovlov Lowdin (Academic Press Inc., New York), 1964. Pp. 400. Price $ 14.00

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NOTES & NEWS

Evidence of water vapour on Venus

Recent research conducted at Johns Hopkins Astrophysics and Physical Meteorology Laboratory in Baltimore, Maryland, by means of a day-time balloon flight carrying a robot telescope at an altitude of 87,500 ft revealed the presence of water vapour on the planet Venus. This was achieved by observing the absorption of certain infrared wavelengths in sunlight reflected by the clouds on the planet. When the balloon reached the altitude of 87,500 ft where the terrestrial water vapour is negligible, a clock mechanism opened the sides of an unmanned gondola carried by the balloon and placed it in a position to observe Venus with the help of sun sensors. Later a star tracker 'locked' the telescope on Venus for 2 hr during which period spectroscopic observations were recorded. The gondola with the recorded data was recovered intact by means of a safety parachute. A study of the recorded information indicated that there are vast amounts of water vapour above the reflecting layers of Venus and the clouds around it may constitute water and not dust as hitherto believed. The study of the presence of water vapour on Venus has a bearing on space travel. From the present investigation the amount of water vapour on Venus has been estimated with a relative precision of 5 per cent [*J. Franklin Inst.*, **277** (1964), 622].

Violation of time-reversal invariance principle

A recent experiment performed by a group of research workers at the Princeton University indicated the violation of the crucial principle of time-reversal invariance, which forms a basic assumption in all existing theories of particle physics. This principle states that it is impossible to say whether an event is taking place forward or backward. The experiment was based on the observation of the nature of the mode of decay of K_2^0, one of the four members of the K meson family (K^-, K^+, K_1^0 being the other three). The theory governing the decay of such particles includes the 'CPT' rule according to which particle reactions are indistinguishable from their time-reversed, antimatter mirror images. If C and P are conserved, K_1^0 (which has a CP value of $+1$) can decay into pi-plus meson (π^+) and pi-minus meson (π^-). But K_2^0 is forbidden to do so because it has a CP value of -1. If K_2^0 were also to undergo a decay similar to that of K_1^0, the CPT rule could be preserved only by a violation of the principle of invariance of time-reversal. Earlier efforts to detect experimentally the forbidden two-pi decay of K_2^0 which provides a crucial test for CPT rule were unsuccessful. Previous experiments were sensitive enough to have detected one two-pi decay among 300 decays of other types. In the new experiment one in every 500 K_2^0 decays was observed to be of the two-pi type. Fifty such events were recorded. Experiments in which violation of T alone can be tested apart from CP are now being explored. One proposed test is to measure the spin or angular momentum of the mu meson when a K meson decays into a pi-meson, a mu meson and a neutrino. If time-reversal invariance is true, the number of mu mesons spinning in one direction with respect to a plane in a certain way should be exactly equal to the number spinning in the opposite direction. If the observations are contradictory to this, the violation of time-reversal invariance will be confirmed [*Sci. Amer.*, **211** (No. 3) (1964), 81].

Rapid determination of auroral heights

A new system developed at the Defence Research Northern Laboratory, Fort Churchill, Manitoba, Canada, has reduced the time and labour required for parallactic determination of auroral heights. In the system used hitherto for the determination of auroral heights, computations are necessary for the position of stars in the photographs taken to allow correct orientation of the images of the aurora on 'nets' previously constructed. To cover large portions of the sky many 'nets' are needed and rough calculations must be made in order to point the cameras at the same part of the aurora during exposures. Because of this labour involved in computations for the 'nets', it is not possible to get both cameras pointed at the same auroral feature while studying fast moving auroral forms. Another disadvantage of the conventional system is that during the flight of a rocket into an auroral display it might not be possible to obtain the height at the point of entry of the rocket because of the considerable horizontal extent of the arc traced in the photograph of the moving rocket. The new system which is free from these defects consists of two wide-angle or 'all-sky' cameras at a fixed separation of 21·65 km. Simultaneous photographs from the two stations are projected on a predetermined grid from which the parallax can be read directly. The slant range from the main station and the height above the earth of the auroral point can be evaluated from the elevation of the point from the main station and the distance between the stations, using a nomogram. Apart from the short time (10 min.) required in evaluating the auroral heights, the new system has other advantages over the conventional system. These are: (i) The method does not require pointing of the cameras at the aurora and consequently any well-defined arc can be studied with scanning spectrometers for rotational temperatures and ratios of emissions of lines; and (ii) considerable lengths of arcs (as much as 350 km.) can be studied for the orientation and variation with height of the auroral arcs [*Canad. J. Phys.*, **42** (1964), 1813].

Anomalous electronic conduction in rare gases

Observations made at the Electrical Communication Laboratory, Musashino-shi, Tokyo, on the anode current-voltage characteristics of inert gas-filled triodes have shown anomalous current maxima at

applied anode voltages corresponding to the first excited potentials of the ambient gases. With increasing gas pressure the current peaks reach a high value. These characteristics have been observed to be peculiar to heavy rare gases such as xenon and krypton and are not observed in argon, neon and helium. The current peak has been found to disappear when a small amount of a gas of diatomic molecules is mixed with the original gas. From a study of the dynamic and static characteristics of this phenomenon, it has been proposed that this unusual electronic conduction through neutral rare gases is due to an anomaly concerning the scattering process between electrons and metastable atoms, similar to the Ramsauer effect. By using the negative resistance region of the observed maximum in anode current-voltage characteristic as a circuit element, experiments on the design of an oscillator were made and it has been found that oscillations at frequencies up to 50 Mc/s. could be produced with large amplitudes [*J. phys. Soc. Japan*, **19** (1964), 1925].

Beam-lead structure for semiconductor devices and circuits

A new type of structure for semiconductor devices and circuits which will simplify fabrication and assembly procedures has been devised at the Bell Telephone Laboratories, New York. The structure uses strong electrical leads, termed 'beam leads', to provide mechanical support for the semiconductor and to make electrical connections. The beam leads (made of gold and 10 μ thick) are integral parts of the devices and circuits and extend out from the structure like cantilever beams to form both electrical and mechanical connection to a header or substrate. For integrated circuits, the beam leads also form the electrical intraconnections between components.

One of the main features of beam-lead integrated circuits is the simple way in which electrical isolation of components is accomplished: all unwanted material between components is removed; at the same time individual circuits are being separated. The beam-lead intraconnections are then left to support and electrically connect the components. Unlike other techniques in use today, no additional diffusion or processing steps are required to isolate components. In these circuits parasitic capacitance between components is negligible, making them suitable for ultra-high speed switching applications. Another feature of this type of structure is that semiconductor wafers or chips which may contain either single devices or entire circuits can now be connected directly to headers by beam leads. Previously, semiconductor wafers were first bonded to the header to keep them in place, and then extremely fine wires were individually connected to circuit elements on the wafer; these two steps are unnecessary with beam-lead devices or circuits. Beam-lead devices and circuits such as diodes, moderate and ultra-high speed transistors, and ultra-high speed logic circuits have demonstrated their physical ruggedness by successfully passing tests which include thermal ageing in 360°C. steam and centrifuging to forces greater than 1,00,000 times the gravitational force [*News from Bell Telephone Laboratories, New York, Release dated* 29 *October* 1964].

Simple solar or gas-powered generator

A new kind of power plant containing a turbine of advanced thermodynamic design which can be operated with solar energy or gas fuel has been designed by the National Physical Laboratory, Jerusalem. The new design minimizes the number of moving parts and obviates some maintenance problems. This will be useful in remote areas where electricity is not available or where fuel maintenance is difficult. The turbine is operated by an organic vapour, and many usual controls are eliminated. The unit has only one moving part, viz. the wheel of the turbine that carries on its shaft the rotor of the generator, contains no brushes or commutators on the generator and requires no oiling. The low operating temperatures do not pose any maintenance problems and explosion is ruled out because of lower pressure on the boiler. A 1 kW. power plant could supply power for irrigating 7·5 acres, lighting a village of 25 families and will be useful for communications. The laboratory planned a range of power of the plant from 150 W. to 10 kW. or more. The cost of solar-operated and gas-fuelled units is expected to be about $ 2000 and $ 1000 respectively [*New Scientist*, **24** (1964), 31].

Thermal conductivity of gas mixtures

A paper presented to the Conference on Thermal Conductivity at the National Physical Laboratory, Teddington, UK, has indicated the possibility of theoretically evaluating the exact value of the thermal conductivity of gas mixtures from their molecular properties. The conduction of heat through gas mixtures is one of the apparently simple physical processes which has so far eluded exact quantitative explanation, though it should, in principle, be possible to predict its value exactly, since the heat conduction is caused by molecular interactions. Theoretical models used for evaluating the thermal conductivity have so far been only confined to the assumption of spherical molecules which differ only in mass and radius for different gases. As such, these models could make exact prediction only for gases consisting of single atoms. Hence, in practice, the theoretical expressions can be made to predict the observed values in gas mixtures only by introducing additional constants in the theoretical expression. These constants differ in value for different gas mixtures and no physical significance for these constants has been given so far. In the paper presented at the conference on thermal conductivity, two factors have been taken into account, viz. (i) the obstruction of the motions of molecules by one another in different mixtures and (ii) the transfer of heat energy from one molecule to another of a different gas. An analysis of the effect of these two factors in the case of gas mixtures gives an actual physical significance to the constants introduced in the theoretical expression to make them predict the observed values. Further study along these lines is expected to give a quantitative explanation of a number of

gaseous transport phenomena, such as diffusion, viscosity, etc., of gas mixtures [*New Scientist*, **23** (1964), 231].

Measurement of small temperature changes

An improved technique of measuring small temperature changes of the order of 10^{-3}°C. has been developed at the Mathematical Department of the Technical School, Plzen. The technique will be useful in the study of magneto-thermal effects where measurement of such small changes of temperature is necessary. At present, small temperature changes are measured, by using a large number of thermocouples, each being connected in series with the intrinsic primary winding of a transformer, the secondary winding of which is connected to a mirror galvanometer. This technique has the disadvantages that (i) the primary windings in series with the thermocouples have to be adjusted to be identical in all respects and (ii) the time constant of the solenoid (in which the specimen, the temperature change of which has to be studied, is kept) has to be increased substantially so as to reduce the influence of eddy currents. The new technique, in addition to being free from the above shortcomings, has quick response to temperature changes. In the new technique, the thermocouples are replaced by a single thermistor (placed inside the sample of diam. 4 mm. and length 10 cm.) forming one arm of a Wheatstone bridge. The resistance of the thermistor as well as the power supply for the Wheatstone net were chosen so that the output has maximum sensitivity to temperature changes at the room temperature. Observations made have shown that a temperature change of 10^{-3} C. produces an output current of 0·005 μa. This current, passing through the output impedance, gives an output voltage of 75 μV. This output voltage is recorded after amplification, using a suitably designed measuring circuit [*Czech. J. Phys.*, **14** (1964), 555].

A new pyrometric standard lamp

A radiator lamp which can effectively replace the tungsten strip lamp (at present used as a pyrometric standard source) and has a number of advantages over the tungsten strip lamp has been designed by the scientists of the Standards Division of the National Physical Laboratory, Teddington, in collaboration with those in the Hirst Research Centre of the General Electric Co. Ltd. Though tungsten strip lamps have been found to serve well both as a standard source of luminance and in particular for the calibration of optical pyrometers in the visual region of optical pyrometry, the accuracy cannot be increased except by imposing severe demands on the operating conditions which are difficult to achieve. Further, it has been observed that there are variations in the surface luminance of the tungsten strip lamp, which increase as the filament becomes thermally etched. It has also been observed that there are differences in the polarization of light emitted from different parts of the filament. The new pyrometric standard source overcomes these difficulties and provides with a uniform disk of light independent of surface variations. The full radiator is a tube of tantalum (diam., 2 mm. and length, 45 mm.) mounted horizontally at the centre of a spherical glass bulb (diam., 150 mm.) with quartz windows for sighting axially down the tube. The tube is formed from a strip of tantalum and is welded along a seam beneath the tube. At its centre is placed a brush of very fine tungsten wire so that, when viewed ' end-on ', a very ' black ' surface is presented. A tantalum diaphragm with 1 mm. aperture is placed at a short distance from one end of the tube. The radiations from this aperture approximate the radiations from a full radiator. Near the opposite end of the tube is another diaphragm completely closing the tube. This experimental design has been tried with satisfactory results in a vacuum lamp operating up to 1550°C. and in a gas-filled lamp up to 2500°C.

The advantages accruing from the use of this type of standard source are: (1) The true temperature, the luminance temperature and the colour temperature are the same; (2) Changes in the surface conditions of the refractory body would not affect directly the calibration of the lamp; (3) The disk of light to be used is well defined and is uniform in luminance (variation, ±0·1 per cent), thus satisfying the fundamental requirement of a standard source; (4) Variations in luminance and degree of polarization with angle of emission are eliminated; and (5) A higher maximum luminance temperature is achieved for the same true temperature of the refractory body [*Nature, Lond.*, **202** (1964), 686].

A new X-ray tube for spectrochemical analysis

A new double target X-ray tube developed by General Electric is capable of performing X-ray emission spectrochemical analysis for a broad range of elements. This tube contains chromium and tungsten targets which can be externally switched to give almost instantaneous spectrum selection. The chromium target is designed for use with elements of atomic number 22 and below and the tungsten target for the other elements. The chromium-tungsten target combination is selected as the best for optimum excitation of a number of elements. Chromium target provides a 2-to-1 gain in sensitivity and intensity compared to a tungsten tube. This tube will prove useful in X-ray quality control and quality assurance programmes in ceramic, petroleum, chemical mining, foundry and metallurgical industries [*J. Franklin Inst.*, **278** (1964), 156].

Production of gallium by continuous electrodeposition

Gallium metal has been produced at Monsanto Co., St Louis, Missouri, by continuous electrodeposition from 1·5 litres of a 2*M* gallium (III) chloride solution; 200-250 g. of gallium are produced in 6-7 hr at current efficiencies of 60-80 per cent. The electrolysis is carried out using graphite anode and molten gallium cathode which are mounted horizontally and parallel to each other at a distance that permits the required current (50-100 amp.) to pass at a potential of 12-16 V. The current density around each electrode is maintained at 0·3-1 amp./cm.^{2}. Perforation of the anode facilitates the escape of chlorine gas. The

operating temperature is maintained at 70-90°, and the *p*H at about 1; this *p*H prevents the precipitation of gallium oxychloride. The cell should preferably be made of pyrex, quartz and teflon as most metals and other materials are attacked by gallium chloride solution [*Nature, Lond.*, **203** (1964), 749].

Concept of superautocatalysis

The phenomenon of superautocatalysis has been postulated to clarify the mechanism of autocatalytic reactions. While carrying out kinetic studies on the reaction of various oxazolidinones, Dr Wilhelan of Dow Chemical (Midland, Mich.) found that autocatalytic reactions which are inhibited do not resume autocatalytic rates when the inhibiting reagent is used up. Instead the reaction rates are higher than expected. These higher reaction rates have been proposed to arise as a result of a release of an autocatalytic agent which has been tied up with the inhibitor.

A good example of how superautocatalysis can take place is provided by the thermal decomposition of 5-methyl-2-oxazolidinone (A). This compound normally exists as a hydrogen-bonded dimer (AA). It decomposes to form 1 - (2 - hydroxypropyl) - 5 - methyl-2-imidazolidinone (B) and carbon dioxide (C) in a simple first order reaction:

$$2A \rightleftharpoons AA$$

$$AA \xrightarrow{k_1} B+C$$

The imidazolidinone (B) functions as an autocatalytic agent and reacts with (A) to form a 1: 1 molar complex (AB). This complex in turn decomposes to carbon dioxide (C), the imidazolidinone (B) and propyleneimine (D). The compound (D) reacts with (A) to give more of (B) according to the equations:

$$A+B \xrightarrow{k_2} AB$$

$$AB \xrightarrow{k_3} B+C+D$$

$$D+A \rightarrow B$$

The complex (AB) decomposes about 1000 times faster than the dimer (AA). Thus k_3, the autocatalytic step, provides an increasing production of imidazolidinone (B). Therefore, the overall result of these reactions is a higher rate of production of the imidazolidinone (B) and carbon dioxide (C). Cyanuric acid (E) inhibitor reacts with imidazolidinone (B) to give a 2: 1 molar complex (B_2E) according to the equation:

$$2B+E \xrightarrow{k_4} B_2E$$

The k_3 is inhibited from taking place and the rate of production of carbon dioxide and the imidazolidinone drops to k_1 (which is constant with time). After all the cyanuric acid is used up, the decomposition reaction would be expected to become autocatalytic again. But this situation is not encountered; instead, after the reaction remains steady and quiet for a long time at constant temperature, a rapid and exponential rise in the rate of decomposition of oxazolidinone is observed. This unexpected increase has been explained to be due to the release of imidazolidinone (B) stored up in 2: 1 complex (B_2E). The release is caused by the propyleneimine which reacts with the complex to give 2 moles of (B), 4-methyl-2-imidazolidinone and organic acid according to the equation:

$$D+B_2E \xrightarrow{k_5} 2B+\text{other products}$$

It may be seen that for every mole of propyleneimine, two moles of imidazolidinone are set from storage: the autocatalytic agent is itself autocatalytically released from storage. It is for this reason only that the phenomenon has been termed as superautocatalysis. The phenomenon will enable a better understanding of systems which exhibit an explosive release of chemicals or energy without any rise in temperature [*Chem. Engng News*, **42** (29) (1964), 36].

Oxidation by molecular oxygen

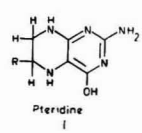
The name 'mixed function oxidases' [Mason, H. S., *Advanc. Enzymol.*, **19** (1957), 128] is attributed to enzymes having two independent catalytic properties, i.e. they catalyse the reduction of one atom of an oxygen molecule, coupled to specific oxygenation or hydroxylation with the other atom.

$$O_2+S+AH_2 \rightarrow SO+A+H_2O$$

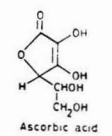
where S, the substrate, is oxidized by two electrons to SO and the biological reducing agent AH_2 is oxidized by two electrons to A. The oxygen in SO comes from molecular oxygen. A biological example of this type of reaction is observed in phenylalanine hydroxylation. The cofactor which donates electrons directly to the substrate is a tetrahydropteridine which is oxidized during the reaction to the dihydro level and phenylalanine is hydroxylated to tyrosine.

In 1954, Udenfriend and coworkers [Udenfriend, S., Clark, C. T., Axelrod, J. & Brodie, B. B., *J. biol. Chem.*, **208** (1954), 731] discovered a non-enzymatic system, by which a number of aromatic compounds were hydroxylated. This system consisted of ascorbic acid, ferrous ion and molecular oxygen, and it was believed that the hydroxylating agent in the reaction is the hydroxyl radical. However, later studies indicated that neither H_2O_2 nor OH^- is intermediate in model hydroxylation reaction. Udenfriend's reaction, in which ascorbic acid takes part in the hydroxylation, can be considered as a model for biological hydroxylations also. Evidence for the similarities of both reactions has been adduced and a possible mechanism of hydroxylation is proposed [Hamilton, G. A., *J. Amer. chem. Soc.*, **86** (1964), 3391].

The cofactor for phenylalanine hydroxylase is a tetrahydropteridine of general structure (I). This contains a partial structure of the enediol of ascorbate. The proposed oxidizing agent in the model hydroxylations is a complex between molecular oxygen and ferrous ion, and enediol of ascorbate of type:

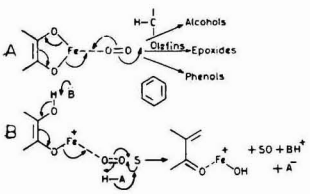


I



By the shift of electrons in structure A, an oxygen atom with six electrons could be transferred from this structure to the substrate, or as in B by a shift of electrons

and a proton the substrate can be hydroxylated. In model systems the recycling of this complex is essential. Fe^{2+} ion could recycle in model systems, but during this oxidation ascorbate is oxidized to dehydroascorbate.



Thus, the necessity for a reducing agent in the enzymatic system has been implicated. In phenylalanine hydroxylase the dihydropteridine is reduced to the tetrahydro level with NADPH. The function of metal ion is to form an electronic link between enediol and molecular oxygen and it allows the conversion of triplet oxygen molecule to singlet species, thereby facilitating the combination of substrate molecules without the formation of radical or diradical intermediates. — P. M. NAIR

Polyribosomes and peptide bond formation in reticulocyte

'Reading' the genetic message is believed to occur in the reaction sequence which leads to the transfer of amino acids from aminoacyl-RNA to their proper sequential positions in the polypeptide chain. R. Arlinghaus, J. Shaeffer and R. Schweet [*Proc. nat. Acad. Sci., Wash.*, **51** (1964), 1291] provide evidence to show that the formation of aminoacyl-RNA bound to the ribosome (the first intermediate with a requirement for GTP) is catalysed by the 'binding' enzyme. The specificity for phenylalanyl-RNA (phe-RNA) for poly uridylic acid-messenger RNA, and the recovery from the ribosome of apparently unchanged phe-RNA after this reaction indicate that this enzymatic step involves the binding of the specific species of transfer RNA to the poly U-ribosome template and is a key reaction in the translation of the genetic message. In addition, the failure of unchanged transfer RNA to inhibit the binding of phe-RNA suggests that this reaction can distinguish between aminoacyl-RNA and the free transfer RNA species. The requirement for GTP is lost as the enzyme is purified. This is possibly due to removal of GTP-degrading enzymes. The absolute requirement for GTP is shown only when the aminoacyl-RNA, poly U and ribosomes are purified. W. Conway [*Proc. nat. Acad. Sci., Wash.*, **51** (1964), 1216] used GTP with phosphoenolypyruvate kinase as phosphoryl feeder for amino acid incorporation studies. He concludes that the ammonium sulphate present in the kinase preparation to be highly stimulatory even in the absence of the feeder system.

The second step in the sequence of the conversion of the phe-RNA bound to the ribosome to the dipeptide, diphenylalanine (phephe), is catalysed by 'peptide synthetase'. The formation of the dipeptidyl-RNA as the first product of this reaction indicates that generally only two phe-RNA can bind to a ribosome at a time. When an aliquot of ribosomes containing C^{14}-phe-RNA and C^{14}-phephe-RNA is incubated with peptide synthetase, GTP and C^{12}-phe-RNA, a tripeptide was formed. Therefore, the synthesis of a polypeptide must involve an alternating sequence of binding reaction and peptide synthetase reaction. The binding of the first amino acid in the chain is the rate-limiting reaction and chain elongation proceeds more rapidly. Preliminary studies indicate that dipeptidyl-RNA is bound more tightly to the ribosome-poly U complex than to the phe-RNA. J. E. Allende, R. Monro and F. Lipmann [*Proc. nat. Acad. Sci., Wash.*, **51** (1964), 1211] separated two complementary factors A and B for phenylalanine polymerization from phe-RNA on *Esch. coli* ribosomes. They identify factor A with the amino acid polymerase and factor B is linked to the GTP effect.

Support for the conclusion that there are two sites for *s*-RNA on a ribosome is given by J. Warner and A. Rich [*Proc. nat. Acad. Sci., Wash.*, **51** (1964), 1134]. They studied protein synthesis in rabbit reticulocytes and conclude that each ribosome active in protein synthesis contains two *s*-RNA molecules. From their study they postulate that the two *s*-RNA sites on the ribosomes are adjacent. Site A (the exchanged site) has the property of loosely binding activated *s*-RNA molecule. When *m*-RNA is present, it binds *s*-RNA selectively using the codon nucleotides. Site P has the property of holding the *s*-RNA with the growing polypeptide chain; this *s*-RNA occupies the next codon in the *m*-RNA strand. Peptide bond is formed with the transfer of the growing polypeptide chain on site P to the *s*-RNA in site A. The *s*-RNA on site P is displaced by the transfer of the *s*-RNA from site A together with its newly attached polypeptide chain. There is a simultaneous translation of *m*-RNA codon from site A to site P so that the *s*-RNA remains attached to the same codon as it is being transferred. This movement from site A to site P would be the basis for the movement of the ribosomes relative to the messenger strand. When site A is again filled with the appropriate activated *s*-RNA, the system is ready to repeat the process. — K. SANTANAM

Biotin as a constituent of bacterial carboxylases

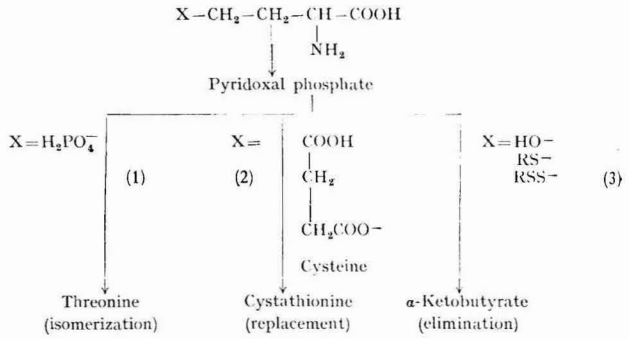
Biotin linked to lysine through the ε-amino group (biocytin) has now been established as the prosthetic group of several carboxylating or carbon dioxide transferring enzymes like acetyl-CoA carboxylase [Waite, M. & Wakil, S. J., *J. biol. Chem.*, **238** (1963), 81], β,β-dimethylacrylyl-CoA carboxylase [Knappe, J., Beidenbick, K. & Brummer, J., *Angew. Chem.*, **74** (1962), 432] and propionyl-CoA carboxylase of liver mitochondria [Kosow, D. P. & Lane, M. D., *Biochem. biophys. Res. Commun.*, **7** (1962), 439]. The purification of the transcarboxylase from *Propionibacterium shermanii* has been reported earlier [Wood, H. G., Allen, S. H. G., Stjernholm, R. & Jacobson, B. C., *J. biol. Chem.*, **238** (1963), 547]. In an attempt to compare the active sites of two biotin containing enzymes, methylmalonyloxaloacetic transcarboxylase and propionyl-CoA carboxylase, S. H. G. Allen, B. C. Jacobson and R. Stjernholm [*Arch. Biochem. Biophys.*, **105** (1964), 494] have

described the purification of propionyl-CoA carboxylase containing tritiated biotin. Cell-free extracts of the mycobacterium grown on a medium containing tritiated biotin was adsorbed on DEAE cellulose and the 0·5*M* phosphate buffer (*p*H 7·4) eluate was subjected to ammonium sulphate fractionation and the 30-70 per cent precipitate was chromatographed on DEAE cellulose with a gradient phosphate buffer *p*H 7·6 (0·7*M*)-*p*H 7·4 (0·1*M*). The pooled fractions were refractionated with ammonium sulphate. The precipitate containing practically all the propionyl-CoA carboxylase was extracted with ammonium sulphate. The 30 and 40 per cent fractions containing the enzyme had a specific activity of 18·1 and was approximately 50 per cent pure. In the final stages of purification all or most of the radioactivity present in the protein appeared to be associated with the carboxylase activity. As contrasted with the propionyl-CoA carboxylase of animal origin, the bacterial enzyme had a broader *p*H range (6·8-8·7) and a greater substrate affinity, whereas the animal enzyme has a rather sharp optimum between *p*H 8·0 and 8·5. Biocytin containing tritium labelled biotin was isolated from the denatured and pronase digested transcarboxylase from *P. shermanii* and propionyl-CoA carboxylase from *M. smegmatis*. The material isolated from oxaloacetic transcarboxylase was shown to contain equimolar parts of biotin and lysine.

Thus, the preparation and purification of specifically labelled enzymes and the means of isolating and identifying the prosthetic group should provide material for comparison of the active site of both oxaloacetic transcarboxylase and propionyl-CoA carboxylase.—S. L. N. RAO

A pyridoxal phosphate potentiated enzymatic elimination reaction

α-Amino acids with electronegative group at the terminal carbon atom give rise to three types of reactions. All these reactions (1, 2, 3) require pyridoxal phosphate, but a non-enzymatic catalysis by pyridoxal phosphate has not been observed [Metzler, D. E., Ikawa, M. & Snell, E. E., *J. Amer. chem. Soc.*, **76** (1954), 648]. α-KG disappear. When DL-[2-C^{14}] homoserine, another substrate for



M. Flavin and C. Slaughter [*Biochemistry*, **3** (1964), 885] report the ability of maleimides to react with and trap a transient precursor of α-ketobutyrate in reaction (3). The γ-enzyme of *Neurospora* mutants H 98 and P 162 catalysing this reaction can also bring about β-elimination from lanthionine.

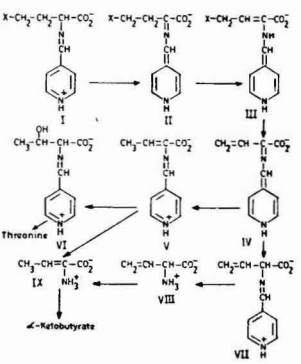
$$\text{Lanthionine} + H_2O \longrightarrow \text{Cysteine} + \text{Pyruvate} + NH_3 \quad \ldots(4)$$

But the inability of maleimides to trap any intermediate in reactions (1) and (4) can possibly indicate the points at which these closely related pathways digress.

The γ-enzyme of *Neurospora* mutants H 98 and P 162 causes a heterogeneous decomposition of cystathionine [Flavin, M., *Proc. International Union of Biochemistry conference on pyridoxal catalysis*, (Pergamon Press Ltd, Oxford), 1963, 377-94] producing a small amount of pyruvate in addition to α-ketobutyrate. Equal formation of total mercaptans and α-keto acid could be shown by including an aromatic disulphide in the reaction mixture [Flavin, M., *J. biol. Chem.*, **237** (1962), 768]. But when C^{14}-N-ethyl maleimide (NEM) was used to trap the mercaptans, equal amounts of pyruvate and homocysteine were formed, whereas the amount of α-ketobutyrate (KB) was much less than the amount of cysteine.

An unknown radioactive product, X Mal, accumulated in the system, but when α-KG was used instead of cystathionine in the system, no X Mal was formed nor did the same enzyme, was incubated with cold NEM, a product chromatographically identical to X Mal was obtained. But again no such X Mal could be detected in reactions (1) and (4).

Two obviously possible intermediates could be either amino crotonate (IX) or vinyl glycine (VIII). If amino crotonate were the intermediate trapped by NEM, it is difficult to explain the non-reactivity of the amino acrylate formed from β-elimination reaction (4) towards NEM. J. S. Fruton [*Biochemistry*, **3** (1964), 885] suggested that the mobile electrons



of compound (IV) constituting a negative charge on γ-carbon atom could react with maleimide double bond instead of acquiring a solvent proton. However, it still remains to be explained as to why maleimides react with compound (IV) in reaction (3) but not in reaction (1).—S. S. RAGHAVAN

Studies on lysosomes

The isolation and properties of the specific cytoplasmic granules of rabbit polymorphonuclear leucocytes were first described by Z. A. Cohn and J. G. Hirsch [*J. exp. Med.*, **112** (1960), 983]. These authors showed that the specific granules resembled lysosomes in the release of acid hydrolases, such as acid phosphatase, β-glucuronidase, cathepsins, etc., by methods involving incubation at acid *p*H, freezing and thawing or exposure to detergents. Further studies by J. G. Hirsch, A. W. Bernheimer and G. Weissmann [*J. exp. Med.*, **118** (1963), 223] revealed that streptolysins O and S obtained from haemolytic streptococci cause the death of intact leucocytes by their action on these granules of white cells. However, these studies failed to reveal whether the lysins acted directly on the membranes of the granules or exerted an indirect effect through mechanisms operative only in the living cell. Further, streptolysins S and O are found to differ in their activities in causing the release of enzymes from mitochondria and lysosomes [Weissmann, G., Keiser, H. & Sernheimer, A. W., *J. exp. Med.*, **118** (1963), 205; Keiser, H., Weissmann, G. & Bernheimer, A. W., *J. Cell Biol.*, **22** (1964), 101] and in causing damage to the specific granules of intact leucocytes [Hirsch, J. G., Bernheimer, A. W. & Weissmann, G., *J. exp. Med.*, **118** (1963), 223].

In a recent communication, G. Weissmann, B. Becher and L. Thomas [*J. Cell Biol.*, **22** (1964), 115] have reported the effects of streptolysins and other haemolytic agents on isolated leucocyte granules. Both streptolysins O and S have been found to lyse the granules at 20°C., the initial rate of lysis by streptolysin O being greater than the streptolysin S. Antimycin and bovine serum albumin inhibit streptolysin S, whereas cysteine activates and a specific antibody inhibits streptolysin O. No other streptococcal exotoxins are found to lyse the granules. Lysis is irreversible and independent of oxidative phosphorylation or intact mitochondrial respiration. The granules are also lysed by lysolecithin, vitamin A, non-ionic detergents and ultraviolet irradiation. The granules of white cells resemble erythrocytes in susceptibility to lysis and other properties but differ from mitochondria in that they do not appear to take up or release water reversibly. Leucocyte granules are not affected by thyroxine and phosphate. The results of these studies point out that white cell granules are similar to lysosomes from other tissues, and also have surface properties in common with erythrocytes.— H. S. JUNEJA

New Periodical

Chio Medica, a periodical published quarterly under the auspices of the International Academy of the History of Medicine, commenced publication from January 1965. The periodical is intended to serve as a medium for the publication of papers of a scholarly character which may be too long or too specialized for acceptance by the ordinary historical or scientific journals. Papers in English, French, German, Italian and Spanish languages will be accepted. The first few issues of the journal will be devoted to proceedings of the first symposium organized by the academy in Basle during 7 September 1964 on 'Materia Medica in the Sixteenth Century'. Annual subscription for the journal is £ 10 ($ 30.00) for libraries, government establishments and research institutions and £ 5 ($ 15.00) for individuals.

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Progress Reports

National Engineering Laboratory, Glasgow

The research activities of the National Engineering Laboratory, Glasgow, reported in the annual report for 1963, show that emphasis has been laid on direct and immediate industrial applications. However, a fair amount of work is also devoted to basic research which may lay the foundations for future developments or provide explanation of phenomena of engineering significance.

Investigations in the field of cold forming of steel is a typical example, the results of which have found immediate profitable application in industry. The laboratory has prepared detailed instructions to the industry regarding the design of the tooling for each operation connected with the process of cold forming of steel, and this has resulted in substantial savings in material as well as increased tensile strength of the products. An investigation to provide the information on the properties of cold extruded products and to find out changes in properties of materials has been completed. From the completed results of this investigation, it will be now possible to predict the hardness and strength of the products from the deformation pattern observed in the process of extrusion.

As a result of investigations made in the hydrostatic extrusion technique, smooth continuous extrusion of long products with a good surface finish without 'pick-up' on the die has been made possible. A new process for cold extrusion of brittle materials has also been developed and the process has been successful in cold extruding beryllium for the first time. With a view to extending the range of applications of fans, by increasing the volume flow and head generation, a fan combining both centrifugal and axial action has been designed. Tests made on the prototype of the mixed-flow fan showed that the design duty could be attained with a high efficiency. The efficiency of hydraulic machines, when evaluated by the thermometric method, requires the measurement of small differences in temperatures between the inflowing and outflowing water. An a.c. bridge capable of measuring accurately such small differences in temperatures has been developed.

The laboratory has taken over the responsibility, from the National Physical Laboratory, of producing linear gratings and now holds master linear gratings with line spacings ranging from 25 to 2500 lines/in. In addition, during the year under review, the laboratory produced a range of master

radial gratings with 90-23,040 lines in a circle. Extensive performance tests have been carried out to assess the accuracy and reliability of the single-flank gear tester developed at the laboratory for checking the errors in relative motion of precision spur gears directly and automatically and the tests over a period of months showed that all measurements could be reproduced within very close limits. Studies were made to provide reliable data on the bulk modulus of hydraulic fluids and from an analysis of these data the probable relationship between bulk modulus and pressure of liquid was derived. Two novel methods of measurement of the bulk modulus of liquids developed at the laboratory are expected to be particularly useful in industrial measurements and even in educational institutions. As a result of investigations made on the application of fully cavitating blades to hydraulic machines, particularly to axial-flow pumps, it has been found that fully cavitating pumps are likely to have two main fields of application, viz. (i) where very high suction lifts were required from a pump in the low and medium speed range, and (ii) where a smaller diameter pump running at very high speeds was required. Since a knowledge of the non-Newtonian behaviour of liquid is of importance in lubrication problems, a study of the visco-elastic behaviour of various lubricants is being carried out. Investigations made so far on a series of polydimethyl siloxanes with a range of steady state viscosities from 10^2 to 10^5 cS. showed that at very high frequencies both the dynamic viscosity and the modulus of rigidity are independent of molecular chain length. Some of the new instruments and measuring techniques developed are: (i) a soap-film technique for calibrating conventional flow meters, (ii) an electronic digital ratio equipment for use with the NEL single-flank gear tester, and (iii) an instrument for rapid determination of thermal conductivity of any liquid with an accuracy of ± 5 per cent.

Hydraulics Research Station, Wallingford, UK

The sixteenth annual report of the station presents an account of the research and design investigations conducted on the various specific problems encountered in a number of projects in England and the Commonwealth countries. The station, engaged in the study, with help of models, of problems connected with open channel hydraulics, such as training and controlling of rivers and estuaries, improvements of ports and coasts, etc., makes available the results of its research investigations to all interested in hydraulic problems and charges a fee for special investigations. The primary fields of study covered are hydrology, hydraulic structures, directional flow in channels, tidal flow, and disturbances in harbours due to long-period waves.

Equipment for controlling tides and littoral currents has been fitted to the Newcastle Harbour model at Many Vale to be used in the many schemes for the solution of the siltation problems. The station carried out research in providing a deeper and more stable shipping lane at the Great Ouse Estuary and experiments with radioactive tracers were conducted to examine the movements of sediment from one channel to another. Studies on disturbances in harbours due to long-period waves were also conducted by (i) developing long-wave recorders, (ii) conducting model tests to find ways of reducing long-wave resonance, and (iii) developing techniques for deriving the significant horizontal movement. The results showed that a reduction of the horizontal movement caused by the long-wave resonance coul be achieved by positioning a wav reflection wall either inside c outside the harbour. The spe trum of horizontal movement in proposed harbour is theoreticall derived with the progressive wa spectrum at sea known and th response of the proposed harbo found from the model study.

The station added some ne equipment, developed new instr ments and improved the existin ones. A conductivity recorder t study the mixing of a fresh wat wave superimposed on a salir base flow was developed. It h a maximum sensitivity of *c.* 10 cn deflection for 0·3 per cent sal A general purpose pneumatic wa machine capable of producing wav at an angle which may be varie over a wide range has also bee constructed which overcomes man disadvantages of the earlier serper type wave machine. The ne machine is cheaper, compact, easil movable and amenable to be bui up in sections to any desired lengt An improved lysimeter for climat logical study which provides continuous record of evapotran piration from a grass covered bloc of soil, thus enabling the study c the relationship between soil moi ture and drainage, an anemomet recorder that registers the run c wind for each day for a week, an tide and current generators a some of the other instrumen designed and fabricated at th station.

The station is presently engage in investigating the way rive meander when they flow throug beds of non-cohesive material, usin sand with a mean grain size of 0·1 mm. and discharges from 0·4 t 3·5 cusec. Another study in pr gress is on the behaviour of tanker moored offshore to a sing fixed tower by measuring the moo ing forces by means of strain gaug attached to the tower and recor ing the movements of the vess photographically.

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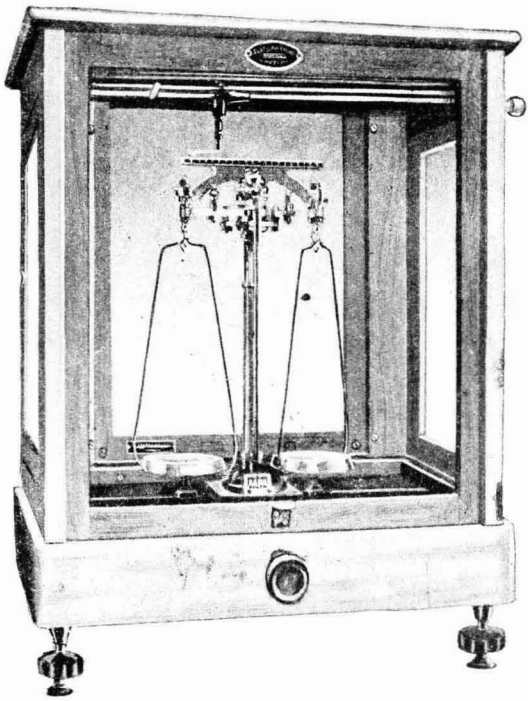

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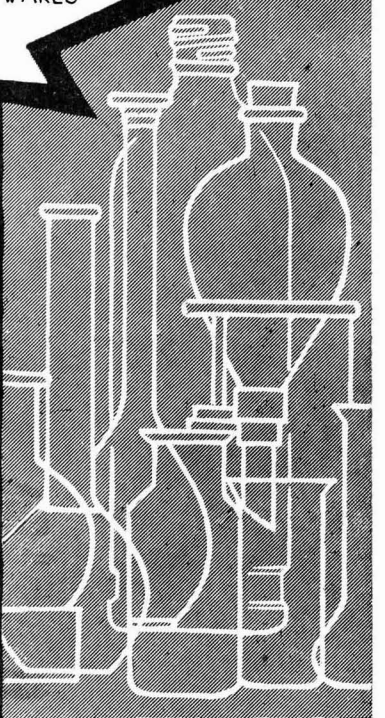

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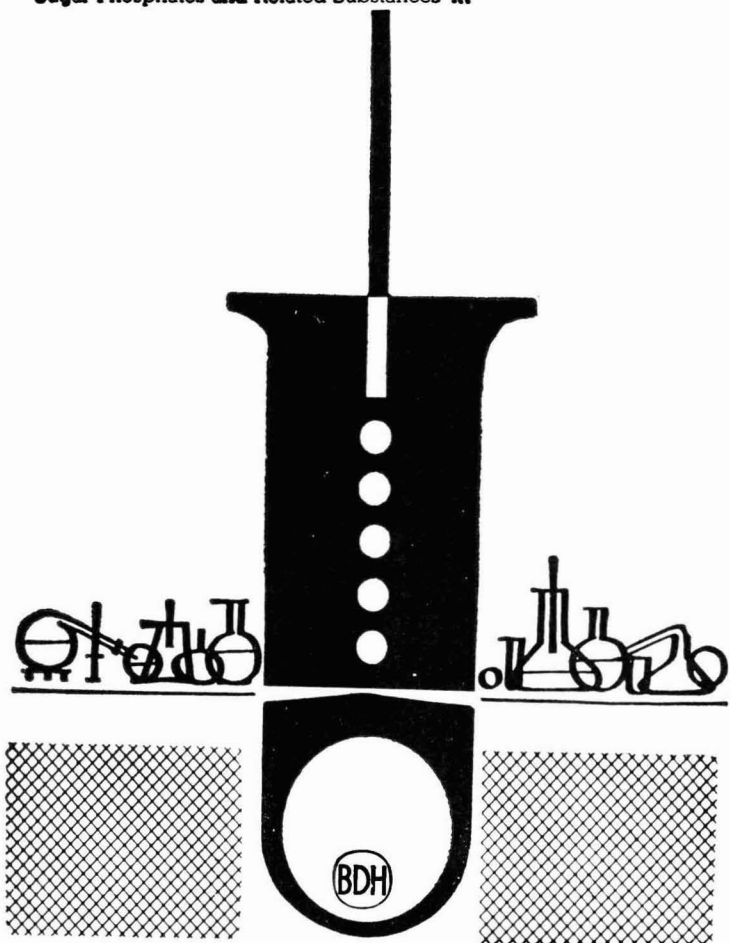

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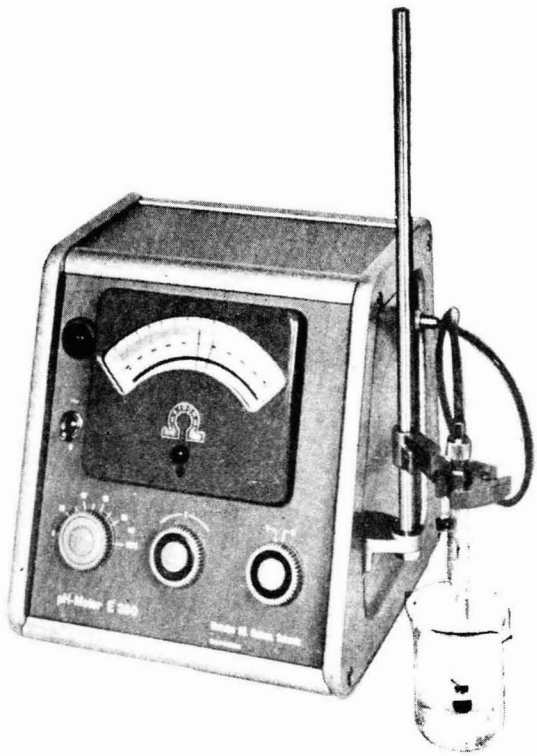

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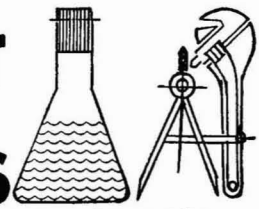

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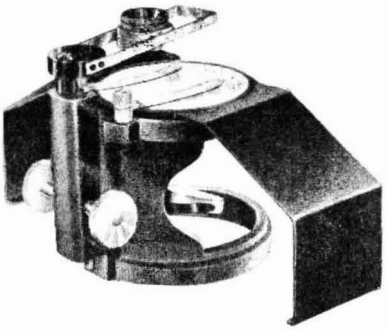

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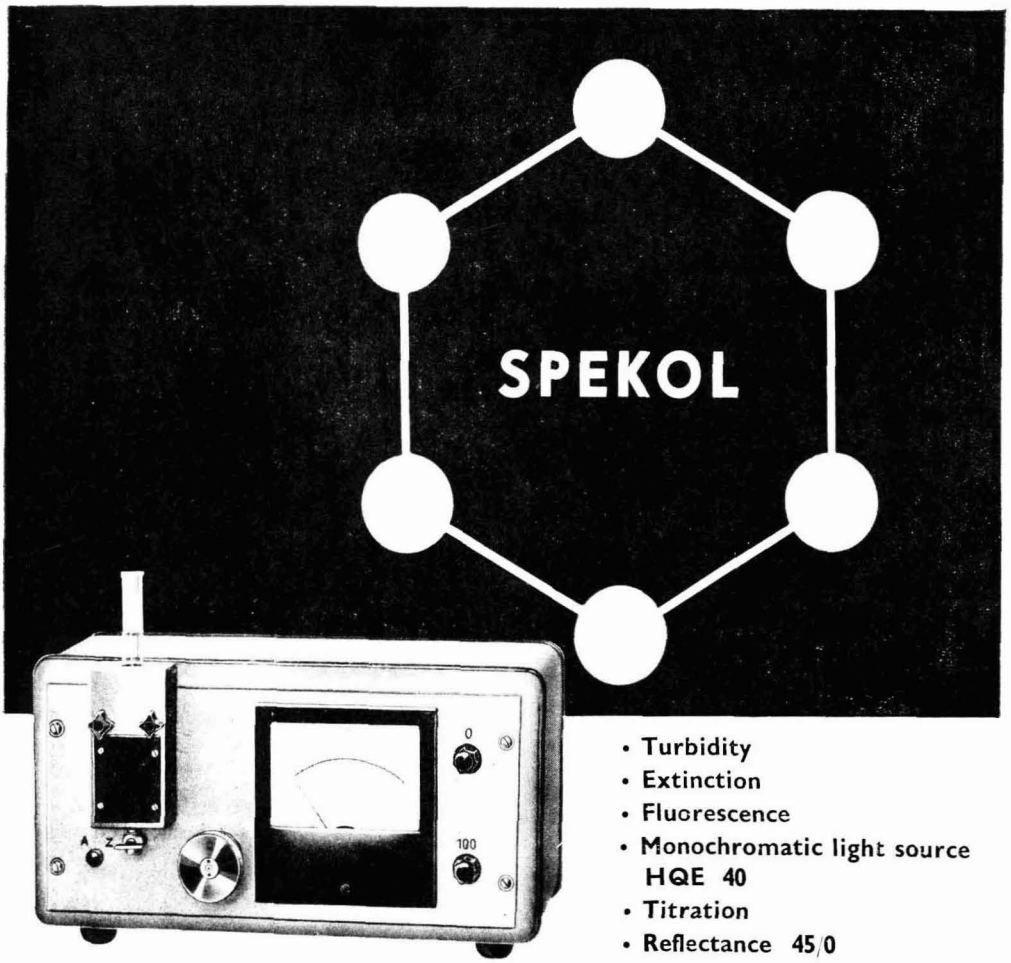

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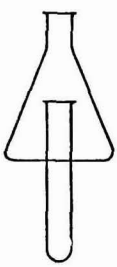

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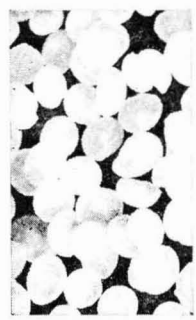

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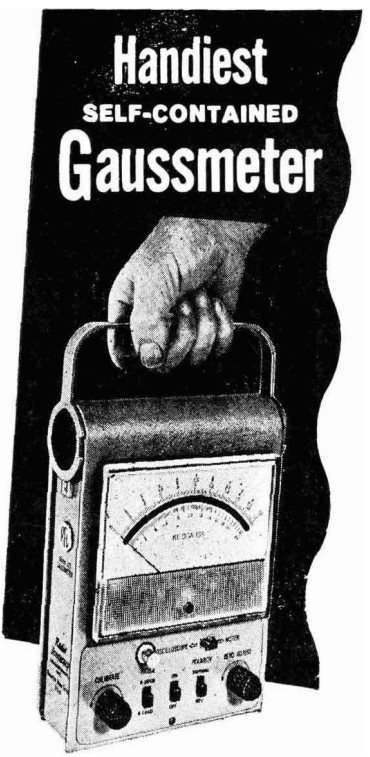

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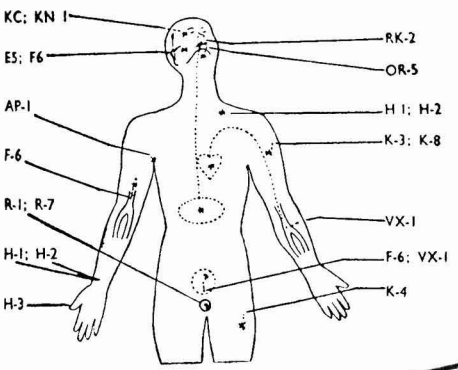

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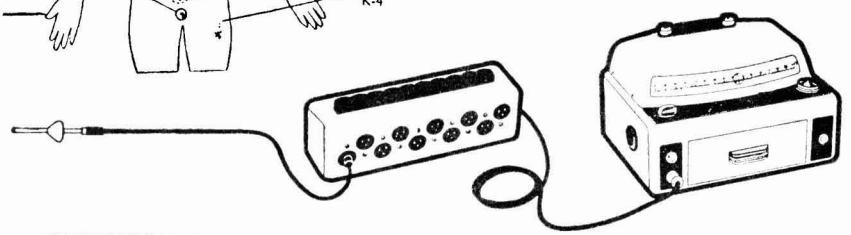

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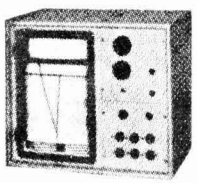

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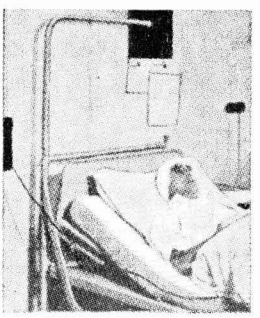

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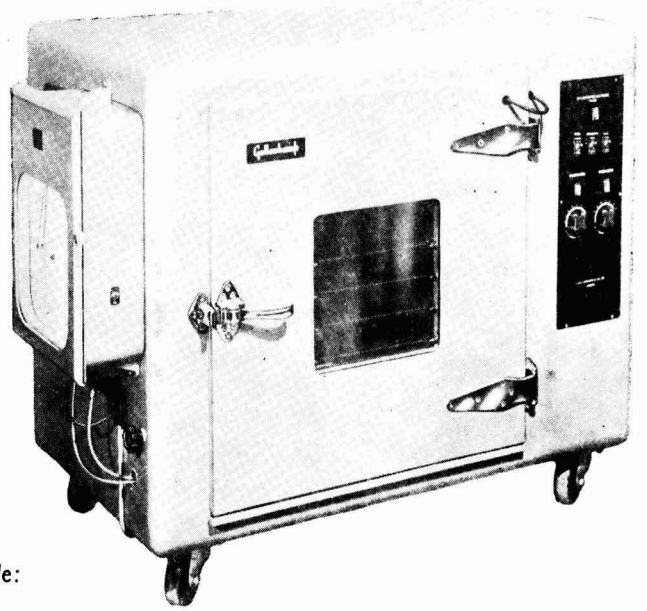

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