The Centennial

SCIENCE ASSOCIATION CLUB

INDIAN ASSOCIATION FOR THE CULTIVATION
OF SCIENCE

THE CENTENNIAL

A SOUVENIR OF THE CENTENARY CELEBRATIONS (1976-77)
OF
INDIAN ASSOCIATION FOR THE CULTIVATION OF SCIENCE

PUBLISHED BY
SCIENCE ASSOCIATION CLUB

Published by
Science Association Club,
Indian Association for the
Cultivation of Science,
Jadavpur, Calcutta 700032.

March, 1977

Cover design : Minakshi Ghosh

Printed by
Mudranika
13A Bipin Pal Road
Calcutta 700026

FOREWORD

I am very happy to learn that the Science Association Club is bringing out a centenary souvenir volume to commemorate the completion of hundred years of the Indian Association for the Cultivation of Science. Early this year, the club, which looks after the cultural and sports activities here, proposed to bring out a souvenir containing popular scientific articles by eminent scientists as a part of the centenary programme of the Association. This was very much in line with the original idea of popularisation of science of the Founder of this Association, the great savant Dr. Mahendra Lal Sircar. In pursuance of that plan, we invited eminent scientists to contribute popular articles on various branches of science. The response has been spontaneous and we are extremely grateful to the writers for their thought-provoking articles. We have tried our best to present a canvas as wide as possible to represent various fields of science but limitation of time has not given us as great a scope as we originally planned. Even then we are very late in bringing out this volume for which we beg to be forgiven.

Finally I thank the organizers of the club who have shouldered the responsibility of the publication with devotion and sincerity.

D. Basu, *Director*,
Indian Association for the
Cultivation of Science.

EDITORS' NOTE

This little collection of popular scientific articles is brought out by the Science Association Club as a souvenir of the centennial of the Indian Association for the Cultivation of Science. When a special publication in the centenary year was planned by the club, it was but natural to decide that it should be a collection of popular scientific writings. Dissemination of scientific ideas to the interested layman was to be one of the important functions of the Association as envisaged by its Founder Dr. Mahendralal Sircar. The Bowbazar premises of the Association had once been a regular venue of interesting popular lectures. Keeping this tradition in mind we decided to collect popular articles from specialists of eminence and make them available at least to the members of the club. The Director himself kindly joined us in approaching a number of scientists for their contributions in the proposed publication, and the response was gratifying. This was a heartening start indeed. Encouragement then came from the Council of the Association in the form of a resolution to consider this publication as an integral part of the Centenary Celebrations. This enabled the Steering Committee for the Centenary Celebrations to arrange for a handsome financial grant which we gratefully acknowledge.

Our contributors are well known specialists in their respective areas. It is a pleasure to thank them for their kind cooperation in this modest venture of ours. Of the fourteen articles received, one was in Bengali. Rather than requesting an English version from the author, we have presented it as such. This may be considered as a feeble expression of our awareness of the necessity of publication of articles on scientific topics in Bengali. The actual publication has been somewhat delayed due to various reasons of which the involvement of almost all the members of the Editorial Board in various aspects of the organization of an International and a National Symposium has been the main one. We tender our humble apologies for this delay to our contributors and to the members of the club. We record here our gratitude to Prof. A. K. Barua, Prof. U. R. Ghatak, Dr. M. Dhara, Sri Amit Ranjan Bhattacharya, Sri Naresh Chandra Lala and all other colleagues who have extended their ungrudging help at various stages of publication of this souvenir. Thanks are also due to the staff and the management of Mudranika, who, inspite of other commitments, readily came forward to comply with all our trying demands.

With these words we present 'The Centennial' to the members of the Science Association Club with the hope that it will prove to be a pleasant companion during some of their leisure hours.

Siddhartha Ray
Debjani Ghosh
Madhuri Guha
Arindam Chaudhuri
Sulapani Bhattacharyya
Editorial Board, Centenary Publication,
Science Association Club.

CONTENTS

SCIENCE ASSOCIATION CLUB

Executive Committee, 1976-77.

President : Dr. Ranajit Kumar Sen

Vice-President : Dr. Siddhartha Ray

General Secretary : Sri Sulapani Bhattacharyya

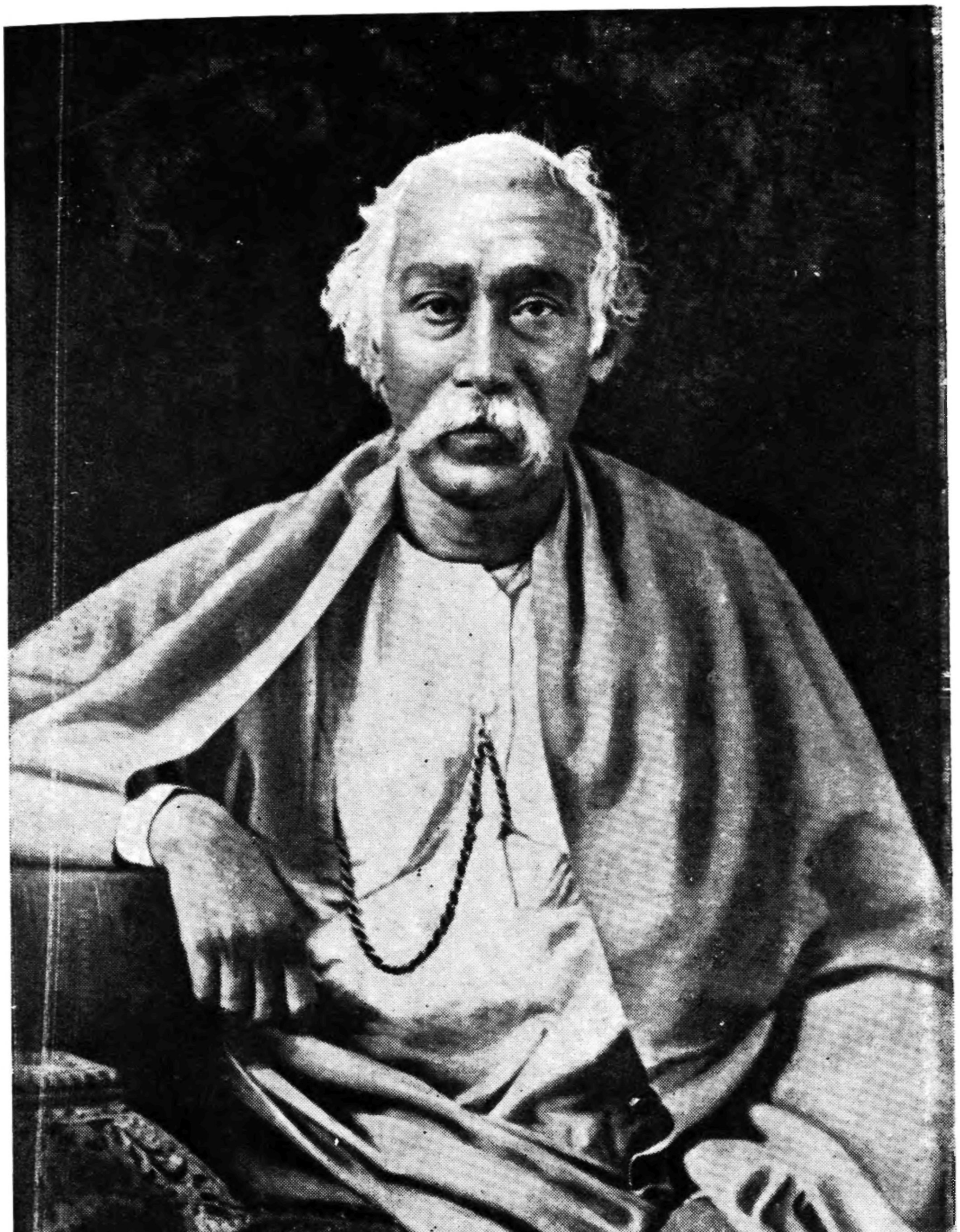
Asst. General Secretary : Sri Ranjit Saha

Treasurer : Dr. Nikhil Das.

Cultural Secretaries : Sm. Samita Chowdhury
Sri Tapan Ganguly

Game Secretaries : Sri Ranjit Das
Sri Asok Das

Members : Sri Jajneswar Chakraborty
Sri Sankar Biswas
Sri Subhas Bhattacharyya
Sri Tarapada Dutta



Dr. Mahendra Lal Sircar

Research Input in Agriculture

S. K. MUKHERJEE
Vice-Chancellor, Calcutta University

Science is knowledge and technology is tool. In both, research is the methodology, Production needs technology. Depending on the availability of resources the technology varies. Of alternative technologies the one which is economically and socially viable becomes acceptable. Technologies must, therefore, take into account the socio-economic and even political conditions of the region of application. These general ideas about science and technology and their applications find ample justification in the field of agricultural research.

There are some advantages in categorising research into basic and applied, even though the line of distinction is often too thin. In the realm of agriculture, applied research is likely to be location specific, because of variation in soil, climate, water condition, variety of crop or animal etc. This requires locational trials before the result of research is finally adopted, and some research elements go into the process in order to adjust technologies to certain specific conditions. This category of research has been termed adaptive research. Even after passing through this stage, a technology may have to face some kind of constraints for large scale application in the field, where it has not only to answer the needs of a varied cross section of farmers of diverse social and economic strata but also varied field conditions which could not all be accounted for on small scale trials. Further adjustments may be required in order to make the technology economically profitable and acceptable to all and sundry. This last stage which is not without some elements of research need, has been termed operational research. The categorisation made in a whole chain of research starting from the laboratory to the farmers' field is not meant to differentiate them in terms of quality and level. Each one of them is equal in importance and prestige and responsibility. In agricultural research the same significance is attached to experiments which are done in laboratories equipped with sophisticated instruments and in the farmers' fields.

An example may be given to illustrate the four categories. The finding of genetic factors determining the yield potential of, say, the seed of a crop, constitutes basic research. Without knowing all of them but having some intuitive ideas one can vary external conditions in order to optimise the yield of the crop in question.

This constitutes applied research, by means of which a package of agronomic practices, e. g. tillage, spacing, sowing, dosages of nutrients, irrigation, pesticides, weedicides, etc. may be developed. These practices having been evolved under one set of available conditions, namely, of soil, climate, etc. may require further trials and modification in order to suit other sets of soil and climatic conditions. This is achieved by means of adaptive research, but even at this stage certain degree of rigour is unavoidable. While applying to farmers' fields such considerations as physical and economic constraints in the availability of inputs, i.e., fertilisers, water, pesticides, etc. according to the accepted package of practices, of resources in men and materials required to comply with the suggested cultural practices, lead to further adjustment, which can be known only by means of operational research, i. e. large scale experimentation in farmers' fields.

Based on the results of research at the different stages referred to above the seed is ready to be released for farmers' use. It is the responsibility of the authority releasing a variety of seed to acquaint the farmers with its numerous characteristics including germination, dormancy duration of the crop to mature, cultural practices, sowing, spacing, tillage etc., input requirements, dosage of NPK fertilisers, soil amendments, if any, micronutrient requirement, irrigation needs, susceptibility to pests and diseases, specific pesticides to be used etc. or any special treatment required in course of the growth and development of the crop to maturity. On a modest estimate it may need 7-10 years to bring out a variety for release. Work is, therefore, started simultaneously on a number of varieties in various laboratories so that some of them at the end of all the trials stand the rigorous tests they are subjected to.

The most difficult stages are the last two in which farmers are to be involved. They are naturally suspicious of any new variety and would hesitate accepting it unless fully convinced of its performance according to their own standards of judgement. For the enterprising farmers having a progressive attitude, persuation to accept a new variety is easy. But for others who form the majority, the barrier is hard to break. It is the responsibility of extension workers who are normally associated with the last two stages to convince the less amenable farmers into accepting an innovation. A good proportion of them are nonresponsive because of ignorance, but a large majority is financially weak and requires credit facilities to venture into anything other than the traditional. The extension workers evolve their own methods of approach based on the ignorance level of farmers, their attitude to techonology, economic and social conditions. A feedback from the last stage conveying success or otherwise of a variety interacts with the initial stages where the researchers start rethinking to endow the varieties with desired characteristics and to remove those that are found unwanted. The various stages in the entire mechanism of agricultural research starting from the laboratory and ending in the field are thus interlinked. The success of the whole process depends on the efficiency with which each stage delivers and receives information and interacts with it. Because of the prevailing academic setup and atmosphere, the universities are the best places for basic research. But partly because of long gestation period of basic research and partly because quick recognition may come through applied research the latter is commonly pursued in the agricultural universities. But it is not to be forgetton that basic research is the fountainhead, and if that is dried up applied research will not yield fruitful results. Men, materials and facilities should be available in all agricultural universities for doing basic research. It is expedient to create in each university one or two schools of basic research, so that the centres of applied research may draw upon the knowledge resources available and created there.

In view of the availability of men, materials and facilities institutes financed by Indian Council of Agricultural Research (ICAR) are also places for basic research. They should engage themselves in certain long range problems in agriculture of national importance. In this matter the scientific panel of the ICAR is the best forum for the identification of such problems and the choice of institutes where they can be tackled appropriately. Otherwise the central institutes should by and large be prepared to carry out applied research.

Adaptive research is best carried out by the state governments which have the requisite technical and administrative bases for this purpose. However, most of the departments have to be strengthened properly and administration streamlined in order to cope with the rapidity with which scientific knowledge should flow and technological operations are to be adapted. A close link and understanding between the universities and central institutes on the one hand, and the technical departments of the state governments on the other, are imperative for a successful transference of research results to the farmers' fields. Agricultural research is inherently multidisciplinary in nature. The almost direct participation of users lends a new dimension to it. A close association between scientists, extension workers and farmers is thus called for.

Basic Research for Development of The Indian Steroid Industry

R. N. CHAKRAVARTI
Indian Institute of Experimental Medicine, Calcutta—32

India is in general warm and humid, very much suitable for biological growth. The country is rich in plants and naturally rich in medicinal plants as well. Many of these plants have been effectively used through ages for amelioration of human suffering. Researches on drugs from plants have been, over a long period, a popular subject pursued by scientists in this country. Most of this work was directed towards finding out the active principles of plants known to have specific medicinal properties. In fact, in the old days the common procedure for such researches on medicinal plants was to take up the particular plant, reputed to have useful medicinal property of one type or another, make extracts of the plant material, proceed step-wise making higher and higher concentrates and search for increasing biological activities in them. In many cases the activities became less in the higher concentrates contrary to expectations. There were numerous other difficulties due to which the actual useful result achieved is very little as compared to the huge volume of work carried out in this direction. One may loosely remark that a particular scientist has carried out a huge volume of research work on medicinal plants, but when it comes to finding out any actual use of any of the results achieved by him one usually gets disappointed. Such work may be termed as 'pure' research and not 'basic' research. A major part of such work may now a days be carried out more or less in a routine manner with the help of modern physical equipment and the computer. Inspite of all the efforts that are still pursued in the classical way in investigations of medicinal plants very little actual progress has been made in recent years, and most of the plant drugs in use today were discovered and established in the very old days. The best known example of more recent origin in this respect is ***Rauvolfia serpentina,*** but with the advent of more useful synthetics its utility even is fading out.

This is evidently the reason why now a days whenever we want to talk about medicinal plants we usually include aromatic plants along with it. The aromatic plants like mentha, citronella, lemon grass, ocimum, etc., unlike the so-called medicinal plants, are destined to play greater and greater role towards economic development of the country. There is considerable internal demand and we are in a position to command a substantial share of the world market. In this respect, the Government has just taken the right step in banning the import of citronella so that the potentialities for developments in the country in this direction may become realities. Such aromatics from plants are not merely used in perfumery, but also in the production of valuable drug intermediates. For instance, lemon grass oil, as is being produced in the country, is rich in citral and is available as a starting chemical for production of vitamin A.

At the beginning of the present century, when Windaus started work on sterols followed by Wieland on the closely related bile acids, few appreciated the usefulness of work in this field, but as it stands today, the steroid chemistry is a distinct and important branch of organic chemistry particularly because of the fact that most of the hormones and even a few of the vitamins are steroid bodies. The subject is, however, rather complicated due to the presence of various types of stereoisomerism at a number of centres of the steroid molecule. A different orientation of the same groupings at one of these centres may bring about a huge change in the physiological activity of the product.

The steroid hormones may be classified as (a) male sex hormones—e. g. androsteron, testosterone ; (b) female sex hormones, e. g. estrone, progesterone ; (c) corticosteroids, e. g. corticosterons, cortisone. Mention may also be made of the norsteroids, e. g. 19-nor-progesterone, which have lately come into use as antifertility drugs. Normally there are three ways of preparation of an organic compound—(i) by direct isolation from natural source, (ii) by total synthesis from simple chemicals, and (iii) by partial synthesis from a closely related naturally occurring organic compound. 1,000 lbs. of beef adrenal cortex yield only about 500 mg of cortisone. So also only 20 mg of progesterone may be obtained from 625 kg. of ovaries of about 50,000 sows. As such, isolation of the hormones from animal glands is not a feasible proposition. Though it has been possible to carry out the total syntheses of a number of steroid bodies, any such synthesis is not applicable on a large scale, not only because of the complicated system of fused rings but also because of the

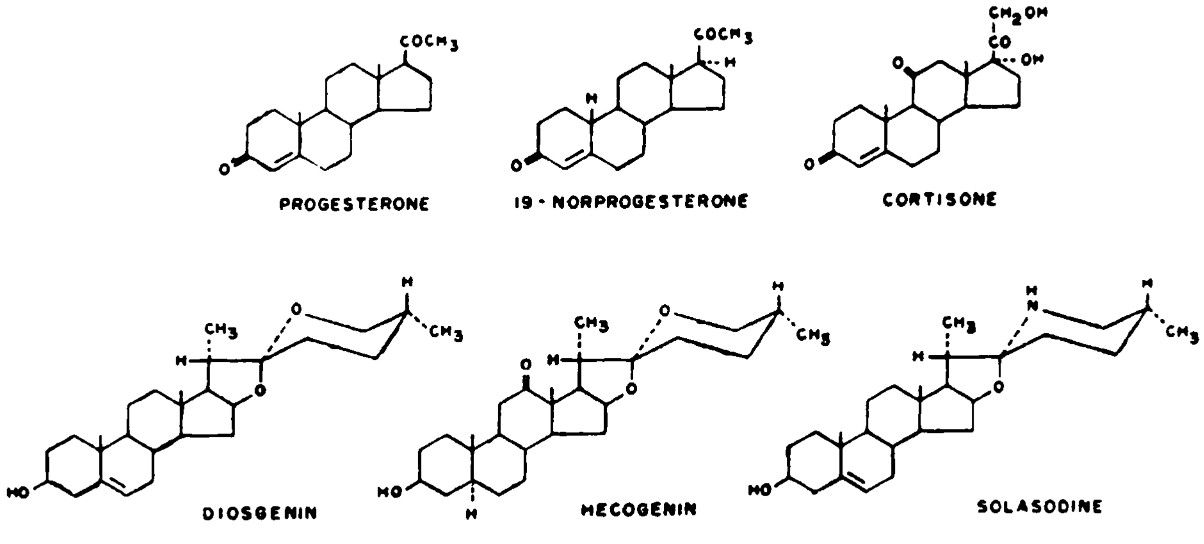


Fig. 1

possibility of formation of a large number of stereoisomers. For instance, even estrone, having one aromatic nucleus, is one of the sixteen possible stereoisomers possessing the same molecular structure. In view of these difficulties, it is necessary to prepare the steroid hormones and other useful steroids by semi-synthetic methods starting from one or other of the easily available naturally occurring steroids.

The naturally occurring steroids are classified as sterols, bile acids, steroid hormones, cardiac aglycones and aglycones of toad poisons, steroid sapogenins, and steroid alkaloids. Steroid sapogenins may occur as free sapogenins or in the combined state with sugars as steroid saponins. In this respect one has to be careful about the triterpenoid saponins and triterpenoid sapogenins which are quite common. Amongst steroid alkaloids mention may be made of conessine group of alkaloids of the bark of the Indian medicinal plant, *Holarrhena antidyssenterica (Kurchi)*. However, most of the steroid alkaloids belong to the group of steroid alkaloidal sapogenins, e. g. solasodine, which usually occur in plants in combination with sugars as saponins.

The final selection of a naturally occurring steroid for utilisation as an intermediate for production of useful steroids depends on easy conversion of the one into the other. However, easy availability of the intermediate from the natural source in bulk quantities at comparatively cheap price is no less important. Cholesterol and some of the bile acids are available in quantities mainly because of slaughter of animals on a large scale for use as food. Accordingly serious attempts have been made for utilisation of cholesterol and the bile acids for the purpose. Ergosterol is a sterol of fungi. It was previously obtained from ergot or *Claviceps purpurea* on rye, and hence its name. It is now a days obtained commercially from yeast specially cultured for the purpose. Ergosterol is used commercially in the production of vitamin D_2 (calciferol) over a considerable period. β-sitosterol is a major constituent of plant sterols or phytosterols. Its potentialities in the preparation of steroid hormones are nearly the same as those of cholesterol with this disadvantage that the former is not so easily available in the pure state in bulk quantities as the latter. Among the phyto-sterols, stigmasterol forms a convenient starting material for the production of steroid hormones, and for this reason it was being extensively used for the purpose till the fifties. The chief source of stigmasterol is soybean oil.

With the object of finding out a rich Indian source for stigmasterol an investigation was undertaken by the author and his team at the Calcutta School of Tropical Medicine on the sterol constituents of numerous Indian plant materials since 1949. It was obtained by them for the first time in this country as the chief sterol from the marshy plant, ***Enhydra fluctuans***, and a method was standardised for isolation of the sterol fraction of a plant material and separation into the constituent sterols. Utilising this method, a survey was undertaken by the writer and his team on the sterol constituents of the seeds of a large number of plants of the family ***Leguminosae*** belonging to the following genera : ***Cassia***, ***Dolichos***, ***Lathyrus***, ***Phaseolus*** and ***Vigna*** collected from different parts of the country mostly through the various Forest Offices. It was observed that seeds of ***Cassia siamea*** yielded γ-sitosterol and those of ***Cassia angustifolia, C. auriculata, C. fistula, C. laevigata, C. sophera,*** as also those of ***Dolichos biflorus*** yielded β-sitosterol as the chief constituent of the sterol fraction. On the other hand, stigmasterol was obtained as the chief sterol from the seeds of ***Dolichos bulbosus (Pachyrhizus angulatus), Dolichos lablab, Lathyrus sativus, Phaseolus aureus*** and ***Vigna catiang***, It was also observed that seeds of ***D. lablab*** and ***V. catiang*** are suitable as alternative Indian sources for stigmasterol in place of Chinese soybean. However, in recent years, the importance of stigmasterol has been very much impaired as a starting material for the steroid industry.

Cardenolides and bufodienolides are another class of naturally occurring steroids present in combination with sugars. Though these are rather rare and costly materials, a tremendous amount of effort was made in 1949 to trace the source of the cardiac aglycone, sarmentogenin, of the South African climber ***Strophanthus sarmentosus***. Expeditions were led from university research laboratories, from research institutes, as well as from the industries of Switzerland, Britain, U. S. A. amongst others, to the dense jungles of South Africa involving enormous expenditure. But all such ventures were unsuccessful.

Of all natural steroids, diosgenin, the steroid sapogenin of Dioscorea yams is regarded as the most suitable starting material or intermediate for the production of a large number of useful steroids of all types. It was first isolated by two groups of Japanese chemists from ***Dioscorea tokoro*** of Japan. However. most of the credit for the utilisation of diosgenin in the production of hormones goes to Professor R. E. Marker, who made a number of extensive botanical trips to the jungles of southern United States and Mexico during his summer vacations. During these trips, he freely mixed with the local people for collecting information about jungle yams used by them as fish poison for catching fish. In this way, he discovered a large number of new steroid sapogenins and established methods for their conversion into steroid hormones. In this respect, diosgenin was found to be the most useful one, though hecogenin, the steroid sapogenin of Agave plants, is also being used for the purpose in view of its availability as a by-product from wastes of the sisal fibre industry. Due to various difficulties, the latter method is becoming less and less popular.

Immediately after the importance of diosgenin in the production of steroid hormones was established by Marker, a comprehensive survey work on the steroid sapogenins of different species of Indian Dioscoreas was undertaken by the author and his team at the Calcutta School of Tropical Medicine. Announcements of the very important results of the investigation were made at symposia held at the Bengal Immunity Research Institute, Calcutta in 1951 and at the Central Drug Research Institute, Lucknow in 1952 and a detailed paper covering the results was published in 1953. The 'Summary and Conclusion' of the paper runs as follows :

> "(1) Diosgenin is a valuable starting material for the preparation of Cortisone and other steroid hormones, e. g. progesterone.
>
> (2) Diosgenin occurs as glycoside (saponin). It has been obtained from *Dioscorea, Trillium* and *Balanites* plants.
>
> (3) Yields of dioagenin from the yams of *D. prazeri* and *D. deltoidea* are exceptionally high as compared to those from other sources.
>
> (4) Steps should be taken for proper utilisation of these two Indian plants."

The Dioscorea plants (family : Dioscoreaceae) are hardy climbers and are divided into two sub-groups depending on whether the plants, as it climbs, twines around the prop to the right or to the left. These plants have often prickly stems. The yams (tubers) of the different species ot plants of this family vary widely in size and shape. Generally, the tubers are soft with white flesh, while others are hard woody. The weight of a yam, depending on the species, may vary from a few grams to 30-40 kilograms. In a number of plants of this family small potato-like bulbils grow along the stem. These, when mature, fall to the ground and after sprouting are suitable for growing the plant. Very thin, bean-like fruits of these plants contain winged seeds, which are also suitable for growing the plants. Yams of *Dioscorea tomentosa (susni alu)* are more or less like potatoes in size and shape and are edible. Yams of *D. alata* (*kham alu*) are also edible but often grow over 20 Kg each and have very odd shape. Yams of some species are inedible, mostly due to presence of large amounts of raphides or needleshaped crystals of calcium oxalate. The edible varieties are used as cheap substitutes for potatoes. Sometimes inedible yams are also taken by hill tribes after processing to remove poisonous constituents like alkaloids, saponins, etc. by washing the boiled yams with hot water. The product is ultimately obtained as white powder similar to wheat flour suitable for making *chapati.* Yams of *D. hispida,* known as *marapashpoli* or deadly strangle cake, are deadly poisonous due to the presence of highly toxic alkaloid, dioscorine. The Bhils poison tigers by placing pounded tubers of this plant in the carcasses of 'kills'.

For the purpose of investigation on the Indian Dioscoreas as carried out by the present author and his team in the early fifties yams of Dioscorea plants growing in the different parts of the country were collected mostly through the Forest Offices of those areas. It was a very well-planned investigation successfully carried out with remarkable co-operation from all quarters. Even the collection of all the different species of Dioscorea yams growing throughout the length and breadth of the country was itself a great feat, and it would not have been possible without the co-operation of the Botanical Survey of India and the numerous Forest Offices in the different areas of the country as also various other organisations and individuals.

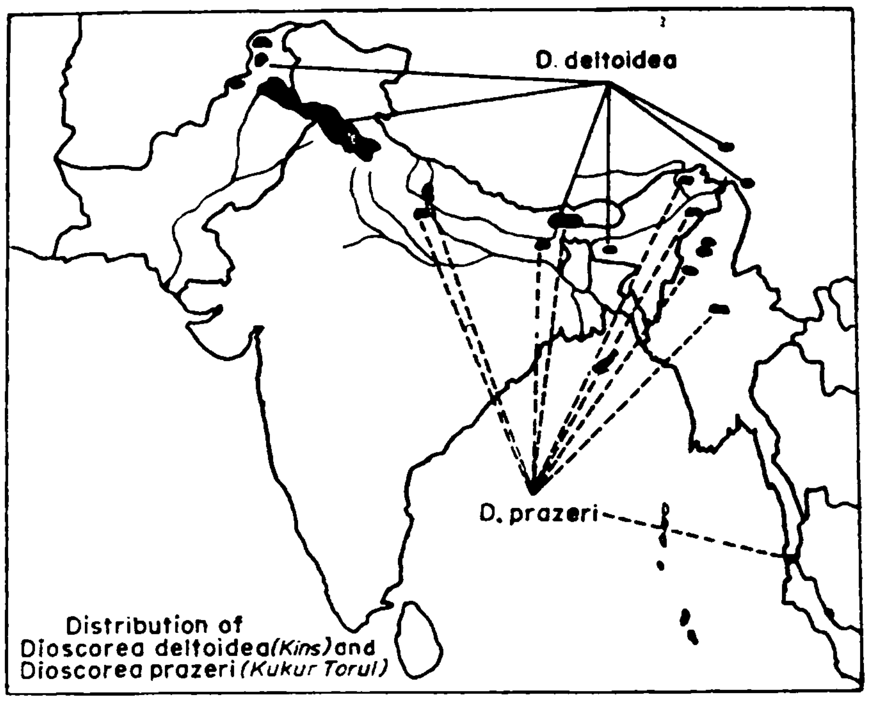


Fig. 2

The yams of the following plants, amongst others, were collected and propely identified prior to the investigation :

Dioscoreas twining
to the right — *D. alata, D. glabra, D. oppositofolia, D. wallichii, D. bellophylla, D. pubera, D. nummularia, D. aculeata* ;

Dioscoreas twining
to the left — *D. esculenta, D. hispida, D. pentaphylla, D. tomentosa D. prazeri, D. bulbifera, D. deltoidea.*

Besides these, yams of a number of unidentified species of Dioscorea plants were also investigated. As stated earlier, yams of *D. deltoidea* of Kashmir, Punjab and Himachal Pradesh and *D. prazeri* of Darjeeling area were found to be rich

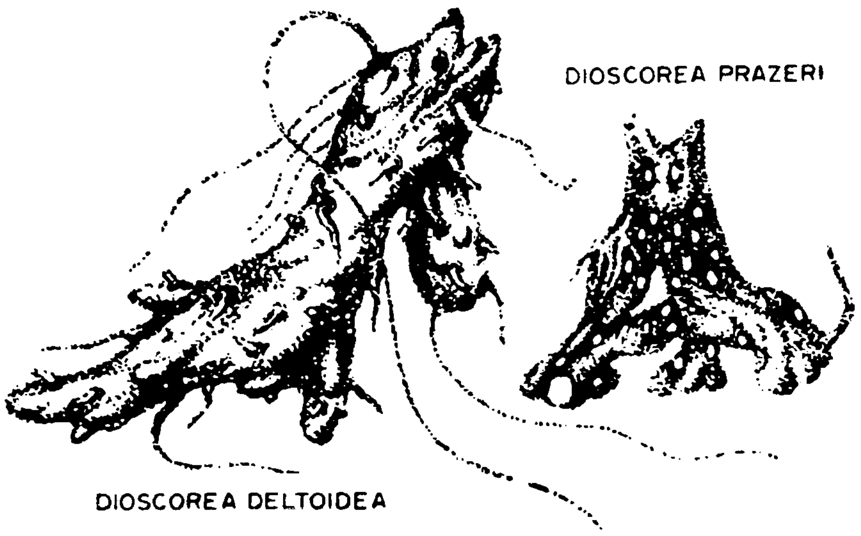


Fig. 3

sources of diosgenin, a valueble steroid intermediate, useful for production of most of the steroid hormones and also the oral contraceptives of the norprogesterone type. These were so long being used locally as soap for washing wool and silk, for washing hair to remove lice, and as fish poison for catching fish. On the basis of results of this investigation, a new industry has developed in this country, the Indian steroid industry.

Yields of diosgenin from *D. deltoidea* and *D. prazeri* are variable. Ordinarily yams of *D. deltoidea* contain 2. 5% to 4. 5% diosgenin though in some cases it may be 2% or even less. Similary, sometimes these yield 5 to 6% and even 6 to 8% diosgenin. In the case of *D. prazeri*, the yield is usually 2 to 2.5%, whereas a variety, *D. prazeri* variety *D. glauca* is found to contain 4 to 4:5% diosgenin. A specimen of yams of *D. deltoidea* obtained from Nepal yielded only a little over 0 5% diosgenin. Serious attempts are being made for cultivation of Dioscorea though the requirement of diosgenin of the industry is still being met from wild yams. Attempts are also being made for growing Dioscoreas and diosgenin by tissue culture.

It is remarkable that none of the right twining Dioscoreas has been found to yield any appreciable amount of diosgenin. Like *D. prazeri* and *D. deltoidea*, diosgenin containing *D. tokoro* of Japan is also a left twining Dioscorea. So also is *D. caucasica* USSR. *D. birmanica* of Thailand is a left twining Diascorea. The yams of this plant are also expected to contain diosgenin.

Solasodine is very similar to diosgenin and differs only in having an imino group in place of the other oxygen of the tetrahydropyran ring of diosgenin. Hence conversion of solasodine into useful steroids runs more or less parallel to that of diosgenin except the very first step. The economic feasibility in this case depends on the comparative position of yield of the sapogenin per annum per unit area and the cost of collection of the plant material ete. P. C. Maiti, who previously worked in the steroid team of the present author and carried out a preliminary examination of alkaloids of Solanum khasianum (Syn. *Solanum myricanthes*) of Darjeeling area, at the Calcutta School of Tropical Medicine along with S. Mookerjee and R. Mathew at the Botanical Survey of India, Calcutta observed quite high percentage of solasodine in seed coat of a special strain of Solanum Khasianum. There is considerable difficulty in this case because of the very light weight of the dry fruit and the thorns of the plant. Some attempts are being made for having thornless plant.

As already mentioned, there is considerable difficulty in utilisation of wastes of the sisal fibre industry for production of hecogenin. This is mainly due to the low yield and admixture with other sapogenins. In fact, the preferred method is not to isolate hecogenin from the wastes, but to first press out the juice of the blades and then get fibre from the pressed out blades and hecogenin from the juice by keeping, due to hydrolysis of the saponin with saponases present in the juice. Indian Agaves are rather poor in hecogenin and also often mixed up with tigogenin. It is also important to point out that progesterone may be produced at a very cheap rate from diosgenia but not from hecogenin, since removal of the oxygen function in ring C of hecogenin immensely increases the cost of production of progesterone from it. On the other hand, for production of cortisone group of drugs microbiological oxygenation at 11-position of progesterone has very much simplified the position with regard to the production from diosgenin, and this compares quite favourably with that for having such drugs starting from hecogenin.

B. Dasgupta, who previously worked in the team on steroids of the present author at the Calcutta School of Tropical Medicine, and V. B. Pandey at the Banaras Hindu University obtained 2.12% diosgenin from rhizomes of *Costus speciosus* (Family : Zingiberaceae). Cultivation of this plant is not expected to be a problem. A large number of wild specimens of the rhizomes of this plant obtained from different places were examined by the present author and his collaborators at the Indian Institute of Experimental Medicine. The yields of diosgenin were found to vary considerably, the highest observed being 1.8% and the lowest only traces. For success with this plant it is necessary to select a high yielding strain and also have proper knowledge of conditions for cultivation of the diosgenin-rich strain.

Recently, the present author and his collaborators have been able to obtain diosgenin in workable yields from *Kallstroemia pubescens* (G. Don) Dandy (family : Zygophyllaceae). It is a weed which can be smoothly cultivated. As the plant is rather fragile and the whole plant is suitable for production of diosgenin, collection of the material involves very simple operation. There are many advantages in using this plant for the production of diosgenin. It is an exotic plant and has somehow got into this country. A weed without stem, it is growing luxuriantly around Calcutta. Possibly it came along with imported food grains. A similar plant, though of a different genus, *Tribulus terrestris* (of the same family, Zygophyllaceae) grows wild throughout the country. Specimens of this latter plant collected by the present author from Delhi and from Hyderabad have been found to contain very small amount of a mixture of sapogenins. It is known as *gokhur* possibly because its small, hard, thorny fruits easily get inside the divided hoofs of cattle and the weed thus spreads to other fields. The Kallstroemia weed, if cultured properly, may ultimately solve the problem of diosgenin production in view of its ease of cultivation, collection, processing, etc.

The spice fenugreek seed, *Trigonella foenumgraecum*, also contains diosgenin, but its economic position is as yet far from encouraging.

The Indian steroid industry has enormous potentialities and there is every reason to believe that with proper efforts it may be possible to develop an export trade of considerable size after meeting fully the internal demand.

Energy and Power

P. R. DASTIDAR

Director, Reactor Group, Bhaba Atomic Research Centre, Bombay

1. Introduction

Even if the most important feature that distinguishes man from other species of animals may be his ability to think, the one singular area of application of this capacity that has been most responsible for the advancement of man from the stone age to the present era of space travel, is the development of the means and ways to extract energy from nature and to utilize that energy to serve his purpose. Over the years from the origin of man to the present day, man has progressed only in proportion to his ability to extract energy from his environment. For many thousands of years the only means of getting energy from nature was the natural utilization of solar energy to produce vegetable products, and the conversion of the food into muscle power either in man or in animals. This pattern of energy use involved pinning down the vast majority of mankind to a life of endless toil and drudgery. This situation changed with the discovery of the steam engine. Until the steam engine was discovered, the main use to which the stored energy in fossil fuels had been put was cooking food. The development of the steam engine was not only the beginning of the industrial revolution, but it was also the beginning of the age when man could put to use his creative ideas without relying entirely on his own muscle power. Moreover, the possibility of converting the heat from coal, oil etc. into mechanical power eliminated the need for man to be always busy in making the basic amenities which are necessary for subsistence. This gave opportunities to man to spend his free time in thinking, and in creating more and more useful devices. The discovery of electricity and of the method of converting mechanical energy into electrical energy, and electrical energy back into mechanical energy caused a rapid expansion of the rate at which energy resources are consumed. The dependence of man on energy can be easily realized from the fact that almost any possible index of the well being of the people of a nation or the wealth of a nation is almost linearly proportional to the total energy consumption by the nation. A correlation that has been often used to illustrate the importance of energy is the relation between the gross national product of a nation with the total energy consumption by the nation. For most of the countries the ratio of the gross national product to the total energy consumption lies within a narrow range of constants and this ratio has remained the same over the years when both the GNP and the total energy consumption underwent changes. Because of the nearly unlimited capacity of energy to produce consumer and luxury goods, and hence to add to the comfort of man's life, the energy consumption by man grew very rapidly over the last one hundred years. It has been estimated that out of all the energy consumed by man over the entire history of the human race almost half has been consumed over the past 25 years or so. Fortunately developments in the commercial aspects of the supply of energy resources during the past three years, have brought about an increased awareness of the limitedness of energy resources and the consequent need to exploit all possible energy resources.

2. Energy Resources

Probably forest fire was one of the earliest sources of intense heat that man encountered. In any case wood was the earliest source of heat and light that man used. Later, towards the twelfth century, coal began to be used as a source of heat. Towards the end of the seventeenth century, the use of oil as a source of light by burning it in lamps was started. By the end of the last century and during the beginning of this century, widespread use of coal and oil in steam engines, internal combustion engines and for electricity generation had started.

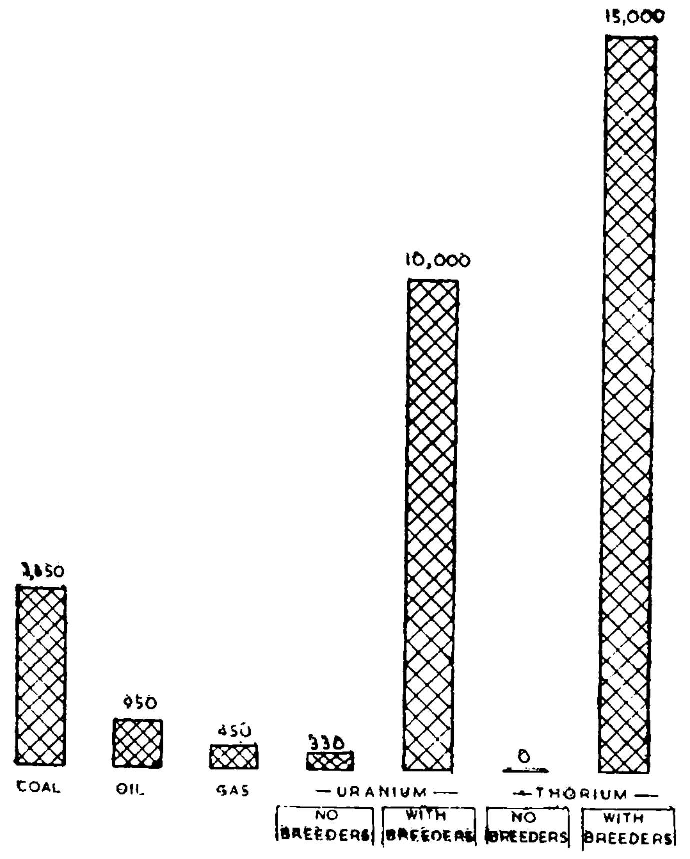


Fig. 1. Potential of Non-Renewable Energy Resources in the World (10^{15} Kilocalories).

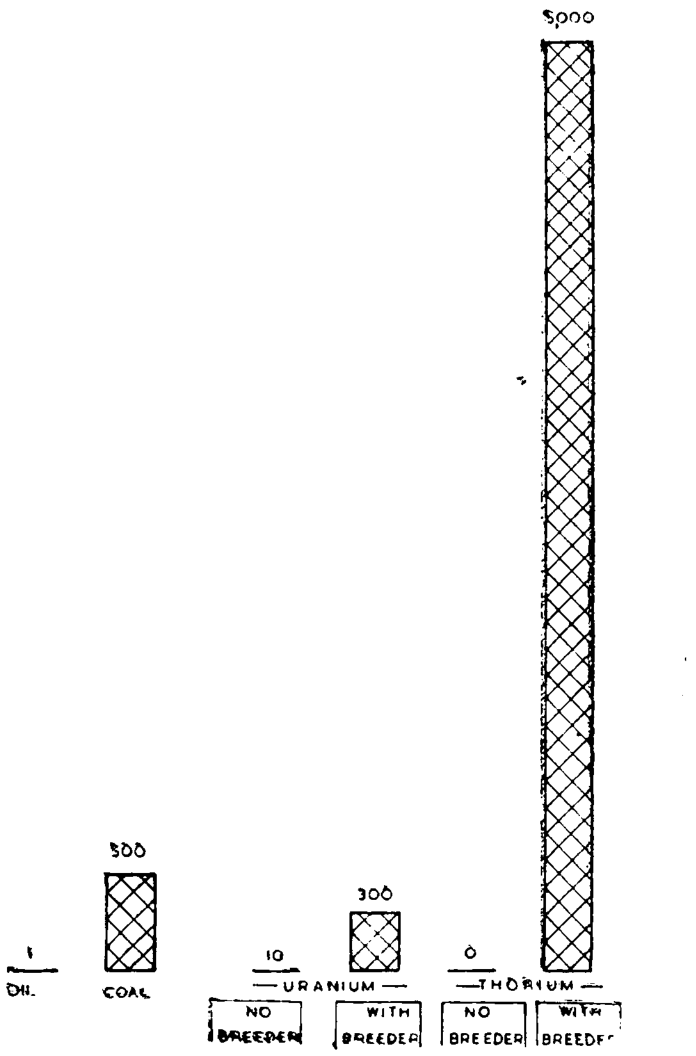


Fig. 2. Potential of Non-Renewable Energy Resources in India (10^{15} Kilocalories).

At present, the most important sources of commercial energy in the world are coal, oil, natural gas and uranium. The potential energy of either naturally or artificially stored water also is being used to produce electricity. In many of the developing countries a major source of energy is non-commercial fuels, like vegetable wastes, cowdung etc. For low temperature applications like domestic cooking, non-commercial fuels are quite satisfactory. However, the fuel value of these products may be significantly improved by better means of utilization.

The commercial fuels like coal, oil, natural gas and uranium are depletable. The energy available from the non-renewable energy resources in the world is shown in Fig. 1. Fig. 2 shows the potential of non-renewable energy reserves in India. Among the fossil fuels viz. coal, oil and natural gas, coal is the most abundant one both in India as well as the world as a whole. The total energy potential from the coal reserves in the world is about four times as much as that from oil and about eight times as much as that from natural gas. The total energy potentially available from a given quantity of natural uranium depends on the type of nuclear reactor that is used to burn the uranium. The total quantity of uranium that is available depends on the type of uranium resources that will be exploited. As the energy content per unit mass of natural uranium is much more than in any other source of energy, the sensitivity of the cost of energy from nuclear fuel to the cost of the fuel is very low. The low cost uranium used in the present day thermal reactors will amount to an energy potential of only about one tenth of the total coal reserves in the world. But with fast breeder reactors, the low cost uranium will be worth as much as two and a half times the total coal available in the world. Further, the presently known thorium resources will be worth as much as seven and a half times the total coal reserves in the world.

Hydroelectricity is a non-depletable source of energy because of the fact that every year the site of hydroelectricity gets replenished by rain or snowfall as a result of water evaporation due to solar radiation. The other sources of energy are the so called non-conventional ones viz., solar energy, geothermal energy due to the large quantity of heat contained within the earth, tidal energy from tidal waves and wind power. None of these sources of energy has been developed to a state of commercial viability, though most of them are being put to use in various special fields to limited extent.

At present the most abundant source of energy in India is considered to be coal. The total gross reserves of coal have been estimated to be about 83 million tonnes amounting to an energy potential of about 5×10^{17} K calories of heat. The estimate of total oil reserves in India has been undergoing upward revisions in the recent past. The latest available statistics indicate that the crude oil reserves would amount to about 130 million tonnes with an energy potential of about 1.3 ×

10^{15}K calories. The natural gas reserves found in India are very small and have been estimated to be about 62 × 10^6 cubic metres, which would amount to an energy potential of about 5.6 × 10^{11}K calories.

The uranium deposits in India are not very large and are sufficient to support about 10,000 MWe of installed capacity from thermal reactors for a period of about 30 years. However, if uranium is used in fast reactors, the energy potential of uranium increases by a factor of about 30-60. Thus the uranium deposits in India may amount to about 1 × 10^{16} K calories of heat if the uranium is used exclusively in thermal reactors, and to more than 3 × 10^{17} K calories if the uranium is used in breeder reactors with the help of the plutonium produced in the thermal reactors. The vast thorium deposits in India will be almost of no use in the absence of a breeder reactor, but will amount to about 5 × 10^{18} K calories of heat energy if it is used in a breeder reactor. One important point that needs emphasizing is that the uranium and thorium resources can be utilized in fast reactors only if the first generation heavy water reactors are constructed so that these reactors will burn the natural uranium and will produce plutonium which can be used to initiate fast breeder reactors. In the absence of the concentrated fissile material plutonium, the uranium and thorium deposits are of no use as a fast reactor fuel. Further, the maximum possible rate of growth of nuclear capacity from fast breeder reactors also depends on the total capacity installed from the heavy water natural uranium reactors.

Among the non-conventional sources of energy, perhaps solar energy holds the best promise. Being a tropical country, the solar insolation in India is relatively high. Taking the average, over a period of an year, the intensity of solar radiation in India is about 600 calories per square centimetre per day. The intensity of solar energy on a typical cloudless day is about 1 KW per square metre.

Geothermal energy occurs as hot springs. Heat from the interior of the earth is already being used to generate electricity in Italy, USA etc. In India hot springs occur in four regions : in Ladak and Manikaran near Himalayas, in the Narmada-Sone valley, in Damodar Valley and in the West coast. Exploration of the Manikaran springs has been taken up. Though the total potential from these hot springs may not amount to much, it has to be realised that these hot springs mostly occur in remote regions and if these springs are developed as sources of power, they could make substantial contributions towards the supply of energy in these regions.

The possibility of generating electric power from tidal waves has been investigated and the total potential in India has been estimated to be about 650 MW, out of which about 460 MW is at Bhavnagar in the Gulf of Cambay and about 125 MW at Navalakhi in the Gulf of Kutch. Exploiting these sites involves considerable work in silt control and in the design and fabrication of a suitable prime mover.

Non-commercial sources of energy, mainly firewood, cowdung and vegetable waste provide almost half of the total energy consumed in India. Though the use of these energy resources in those sectors where they can be conveniently used, results in conservation of the commercial energy resources, often the indiscriminate use of forest wood with no effort to plant new trees in the forest results in undesirable ecological changes. Moreover, cowdung and vegetable wastes could be used more effectively as a source of energy as well as a source of manure.

3. Energy Consumption In India

If one considers the total energy consumption in India and the gross National income, in both the cases, India is better off than most of the countries in the world except about half a dozen of the industrially advanced countries. The well being of the people of the country, however, is measured in terms of the national income or industrial production per capita and not of the nation as a whole. In this respect India has to make significant progress both in the per capita energy censumption and in the per capita gross national product.

Energy consumption can be measured in various units. Though from a scientific point of view the most natural unit for measurement of energy may be kilocalories, very seldom is it used in practice. The most commonly used measure is the coal equivalent tonne. This is primarily because traditionally coal has been taken as the standard fuel. But coal itself often has different energy values, depending on the type of coal, other ingredients in the coal etc. Usually, standard fuel is taken

TABLE—1

Coal Equivalent and Coal Replacement Relations

Sr. No.	FUEL	UNIT	Coal Equivalent million tonnes	Coal Replacement million tonnes
1.	Coal (5000 K Cal/kg)	million tonne	1.0	1.0
2.	Hard Coke	million tonne	1.3	1.3
3.	Soft Coke	million tonne	1.5	1.5
4.	Firewood	million tonne	0.95	0.95
5.	Charcoal	million tonne	1.0	1.0
6.	Fuel Oil, Furnace Oil, Low Sulphur Heavy Stock.	million tonne	2.0	2.0
7.	Kerosene, Liquified Petrolium Gas	million tonne	2.0	8.3
8.	Diesel Oil	million tonne	2.0	9.0
9.	Non-Gasolene Aviation Fuel	million tonne	2.0	7.5
10.	Natural Gas	billion cubic metre	1.8	3.6
11.	Electricity	billion KWH	1.8	1.0

to be coal with a calorific value of 7000 KCal/kg, even though coking coal has only about 6,650 KCal/kg and noncoking coal often has as low as 4,500 KCal/kg. Oil is considered to have an energy potential of about 10,000 KCal/kg. To convert the consumption of oil into coal equivalent, the multiplication factor used by the United Nations is 1.3, though the more often used figure is 1.5. The equivalence of natural gas in terms of coal is 1.33 tonne coal per cubic metre of gas.

Though the coal equivalence is basically dependent on the heat content of the fuel, under certain circumstances this approach may not give any meaningful idea about the usefulness of the fuel. This is especially so when one fuel cannot be easily replaced by another on the basis of the calorific value alone. For example, petrol and diesel oil cannot be replaced by coal on the basis of the heat value alone. A more sensible approach would be to evaluate the amount of coal that will be needed to serve a certain quantifiable purpose in a sector of human activity if the type of fuel that is commonly used in that sector is not available. This argument resulted in the use of another unit called coal replacement tonne. The coal equivalent and the coal replacement relations for the different types of fuels are given in Table I. As can be seen from Fig. 3, about half of the total energy consumed in India is contributed by non-commercial fuels, in which firewood contributes about 65%, the rest being cowdung and vegetable wastes. Though the contribution from the non-comercial fuels has been decreasing over the years, from

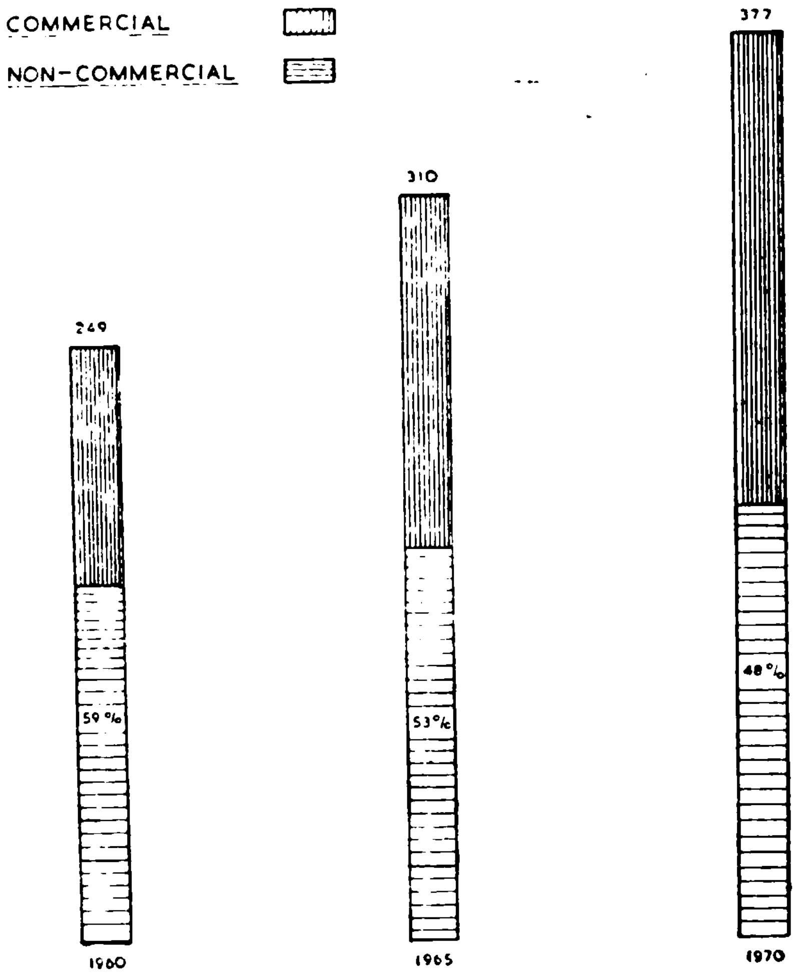


Fig. 3. Non-Commercial and Commercial Energy Consumption in India (Million Tonnes Coal Replacement).

59% in 1960 to 48% in 1970, it is still very high compared to the figures for industrially advanced countries.

Among the commercial fuels, about 40% is contributed by coal and about 49% by oil. The rest is from hydel and nuclear power. The major sector in which coal is used is mining and manufacturing. About 75% of the coal is used directly, in the sense that the heat generated is used as it is. Adout 28% of the coal is used in electricity generation. Almost half of the oil used as a fuel is used for transportation, and more than a quarter is used in the domestic sector for cooking, lighting etc.

Almost all the non-commercial fuels are used in the domestic sector especially in rural areas. About 31% of all the energy consumption in India is from firewood, while vegetable wastes contribute about 9.5% of all the energy consumption in India. Cowdung provides about 7.1% of the total energy. Many activities which machines do in advanced countries are being done in India with the help of animals. There is no reliable account of the energy that is supplied by animals, but it must be very substantial, especially in the sector of agriculture and rural transportation.

4. **Energy Policy for India**

A haphazard and short-sighted approach to the problem of meeting the energy requirements may not always yield satisfactory results, especially because of the rapidly growing energy requirements and the steadily depleting resources of conventional fuels. The attitude that certain energy resources need not be exploited because of one or another reason is no longer widely held. It has been amply demonstrated that to ensure a continued supply of adequate energy, all possible energy resources have to be developed and exploited. The essential problem lies in deciding the optimal rate at which each resource should be developed.

Though the coal reserves in India amount to about 83,000 million tonnes and the present annual consumption is only about 80 million tonnes, it may not be desirable to substantially increase the contribution from coal to the total energy consumption in India. It is a well known fact that though the total coal reserves in India are quite sizeable, almost all of them are concentrated in the central and eastern regions of India. Vast areas of the subcontinent are lying far away from the coal bearing regions. Even now coal transportation has reached a stage where inadequate transport facilities affect industrial activities. Further, electricity generated from power stations located far away from the coal fields would be excessively expensive as the freight rates for transportation of coal increase. Yet another important point that has not been given its due importance is the fact that coal can be an effective source of many valuable petro-chemicals in the event of any further shortage of oil. No other possible source of energy, like uranium, fuels for fusion reaction, solar energy, geothermal energy etc. can be a substitute for coal or oil in petro-chemical industries. Hence there is every need to conserve the coal that is available. Moreover, the maximum possible capacity in mining the coal will impose an upper limit on the rate at which it can be used.

The oil production in India is not yet adequate to meet all the demand. The presently known oil reserves in India may not last for more then 20 years at the present rate of production. It is true that recently there has been some improvement in the total oil reserves. This would enable the nation to reduce the dependence on imported oil and to increase the reserve to annual production ratio. It has to be realised that at present oil consumption in India is the minimum possible, in the sense that it is not used in any sector in which it can be replaced except perhaps in the fertiliser industry. Unlike in many western countries, very little oil is burnt in India for the generation of electricity. Oil consumption can be reduced to some extent if coal liquifaction and gasification technologies are developed to a stage of commercial success.

Nuclear power is beginning to make significant contribution to electricity generation in India. As the amount of energy stored in nuclear fuel is enormously high, transporation of nuclear fuel is not a problem at all, as it is in the case of coal. Hence, to begin with, nuclear power is particularly suited to generate electricity at places located far away from the coal fields. Today about 3% of total electricity generation in India is from nuclear power plants. The share of nuclear power is expected to gradually rise over the coming years and by the end of this century it is likely to be about 16%. Though 16% of the total electricity generation will amount only to about 5% of the total energy consumption, the gradual growth of the role of nuclear power is important from many considerations. Firstly, nuclear power will significantly reduce the need to mine and transport coal. Secondly, the nuclear power programme, though it may appear slow, will prepare the infrastructure for rapid growth of nuclear power after the fast breeder is completely developed. It is anticipated that nuclear power will gradually become the major source of electric power. Another point that may be mentioned here is that even though the total coal reserves in India are relatively large, the amount of coal that can be used in metallurgical industries, viz., coking coal, is very low. It may not last for more than twenty years. Of course, there is a chance that by then technology might be developed to use the non-coking coal in metallurgical industries. Nevertheless, in case it is not developed, nuclear power with suitable type of nuclear reactors can be used to provide high temperature heat for metallurgical industries. Yet another area where nuclear power can be used is in ship propulsion.

Though the uranium deposits in India are not very large, the thorium deposits in India are one of the largest in the world. Once the fast breeder reactor is developed to a stage when it can commercially compete with other types of power stations, the thorium and uranium deposits in India would be adequate to meet the electricity requirements for many countries. A possible long range scheme for the utilization of nuclear energy in India is shown in Fig. 4.

Though so far nothing has been mentioned about hydel potential in India, it has to be realised that about 35% of the present electricity generation capacity is from hydel power stations. The total hydel potential in India has been estimated to be about 41,000 MWe which can be operated at an annual capacity factor of 60%. About 17% of this hydel potential has already been exploited, and another 10% is at various stages of development. There is absolutely no doubt that as much of the hydel potential as available should be exploited as early as it is possible,

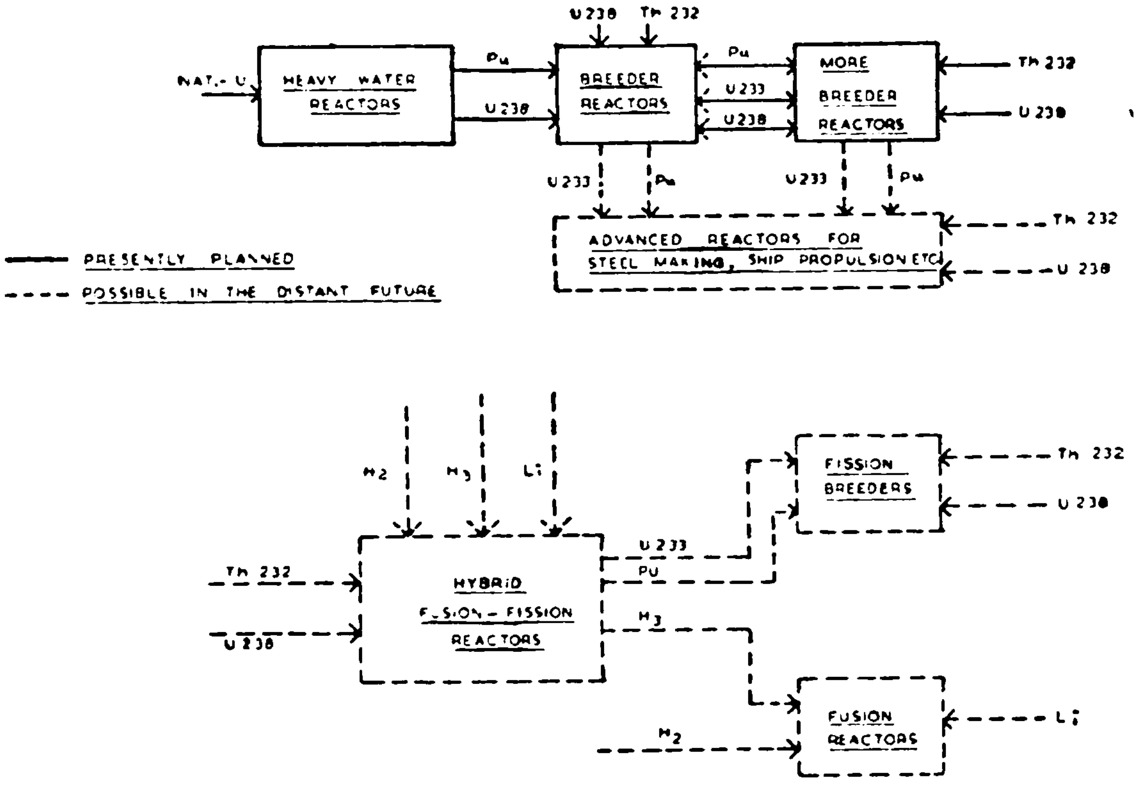


Fig. 4. Possible Long Range Scheme for Nuclear Energy Utilization.

because this is a source of energy that goes waste if it is not used. However, one has to bear in mind that the total demand for electricity in India will exceed the maximum hydel potential available in India within the next ten years. Some of the hydel sites are situated at parts of the Himalayas which are not easily accessible and are very remote from any possible site for industrial development or any other load centre.

5. Other Sources of Energy

Energy is used mostly for heating and for doing mechanical work. In both these areas of application the quantity of energy alone does not convey much information about its usefulness. The temperature at which the energy is available is important both in heating applications and in conversion of heat into mechanical work. It is well known that the higher the temperature at which the heat energy is available, the better the efficiency of converting the heat into mechanical energy. This point is of great importance in utilizing many sources of energy. Though the magnitude of solar energy available to mankind is very large, it cannot be easily put to any practical purpose because of the fact that attainment of high temperature using solar energy is a relatively difficult problem. With low temperature the efficiency of utilization will be very small and hence the power produced becomes very expensive. The same considerations are applicable in the case of geothermal power as well.

The total quantity of energy available from nuclear fission is enormously large. The cost of power produced from nuclear fuel is almost insensitive to the price of the fuel. Hence one can afford to use uranium even from sea water. However, before low cost uranium and thorium get exhausted, fusion reactors are likely to be developed to provide energy. Since fusion reactors use deuterium or heavy hydrogen as the fuel, there will be no shortage of fuel as deuterium is available in the sea water. However, as fusion reactions can take place only at temperatures of the order of a million degree, confining the fuel in a fusion reactor is a technologically difficult problem. Moreover, in a fusion reactor the fast neutrons released per unit energy is about five times more than that in a fission reactor. As fast neutrons cause damage to the materials of construction, fusion reactors will have more serious material problems than fast reactors have.

One possible solution that can be achieved before pure fusion reactors become feasible is to construct coupled fusion-fission reactors so that the neutrons released in the fusion reaction can cause fission in a blanket of uranium or thorium so that more energy will be released. Such a hybrid system has many advantages, the more important ones being the amplification of energy and the fact that the design of the fusion part of the hybrid system is much simpler than that of a pure fusion reactor. A hybrid fusion-fission reactor can be achieved in practice with less technological development than that necessary for the fusion reactor, and it can efficiently make use of the vast quantities of uranium and thorium. Furthermore, hybrid fusion-fission reactors will be able to produce fusile and fissile materials more rapidly than pure fission breeder ractors can do, so that the installed electricity generating capacity can grow more rapidly than with fast breeder reactors alone.

6. Optimal use of Energy

As long as energy is available in plenty, one can use it for everything that one wants to do. But when there is more demand for energy then can be met, it is important that the available energy is utilized in the best possible way. The practice of imposing a uniform percentage reduction in the energy consumption in all sectors may be the simplest way of managing an energy shortage, but need not necessarily be the wisest way of doing it. Under such situations it may be more advantageous to divide all the energy consuming activities into as many number of small sectors as possible. As the importance of energy consumed in the various sectors measured in terms of either its contribution towards the gross national product or in terms of the well being of the society will differ from sector to sector, each sector can be assigned an importance factor or a weight function. Then the total available energy function can be allocated to the various sectors in such a way that within the total quantity of energy available, the sum of the products of the weight factor and the energy consumed in all the sectors is a maximum. Such an optimization exercise will give broad guidelines as to the best way of spending the availabe energy.

7. Conclusion

It is very unlikely that shortage or complete absence of energy will put an end to civilization. From the past experience of mankind, one can legitimately expect that before one source of energy gets completely depleted man develops another source of energy. It is interesting to note that even when a better source of energy is discoverd the earlier source of energy continues to be used for some other purpose. For example, even after wood ceased to be used as the main source of energy, it still continues to be used as an important raw material in many industries like paper manufacturing etc. Similarly even when coal is no longer used as a fuel it will continue to be an important source of many organic chemicals. Atmospheric pollution due to chemicals and accumulation of radioactive wastes which have to be managed for thousands of years have been cited as serious problems associated with increased consumption of energy. However, these are not problems for which satisfactory solutions cannot be found with adequate research oriented in that direction.

Bibliography

1. Report of the Fuel Policy Committee, Government of India, (1974).
2. Energy: Fuelling India's Future. Yojana. Annual Number Vol. XVIII, No. 1 (1974).
3. Energy Systems: Development and Policy. H. N. Sethna, PHYSICS NEWS Vol. 5 No. 3 (1974).
4. Assumptions and Realities in Power Planning. R. Ramanna, Report MIS-73-01. Physical Research Leboratory, Ahmedabad, (1973).
5. The Potential of Nuclear Fuel in Meeting the Energy Needs in India. V. N. Meckoni and M. R. Balakrishnan, PHYSICS NEWS, Vol. 5 No. 3 (1974).
6. Indian Innovations in Nuclear Powers Design. P. R. Dastidar and M. R. Balakrishnan, Hindu: Survey of Indian Industry (1975).
7. The Application of Nuclear Energy for the Generation of Electricity in India. S. K. Mehta, J. Industry and Trade, Aug. 1975.
8. Energy Development in India. P. K. Bhatnagar, PHYSICS NEWS Vol. 5 No. 3 (1974).

Enkephalin—A Key Molecule To Our Understanding of Pain and Addiction

J. J. GHOSH

Department of Biochemistry, Calcutta University, Calcutta—19.

Introduction

Although pain is a characteristic sensation experienced by all living bodies—its exact mechanism has not yet been clearly elucidated. There are several hypotheses in physiology, pharmacology, biochemistry as well as in medicine to explain this common disorder in our life. Although the association of opium with pain relief has been known from the days of antiquity, the isolation and characterization of morphine alkaloids, the major active component of opium, in the early nineteenth century, gave further impetus to our understanding the analgesic mode of action by a vast number of morphine related drugs which are commonly referred to as "opiates". Besides opiate analgesics, there are non-opiate analgesics like aspirin and related drugs which are effective in the treatment of moderate pain. The "opiates," on the other hand, are particularly useful in relieving severe, persistent pain.

Search for Opiate Receptors

It has been assumed for many years that drugs generally exert their actions by being attached to specific chemically defined portions of the tissue, called receptor sites. This concept was based on the high structural and stereochemical specificity exhibited by many drugs and the dose-response relationships in the action of mutually antagonistic drugs. Receptors are macromolecules, predominantly protein, located generally on the membrane of cells, specifically affected by drug, hormone or neurotransmitters. During early seventies, intensive research investigations led to the identification of opiate receptor or receptors in brain and other tissues, mainly based on the following evidences :

(a) the opiate drugs exhibit extreme stereospecificity ; for example, levorphanol exhibits analgesic activity, whereas dextrophan, its stereoisomer does not; (b) minor changes in chemical structure result in the creation of potent opiate antagonists, such as nalorphine and naloxane; (c) etorphine, the most potent among the morphine group of drugs, exhibits stereospecific binding at levels that are proportional to its biological response.

Distribution of Opiate Receptors

By measuring the binding of tritium-labelled opiate compounds, many important mysteries about the action of opiate drugs were soon revealed and as a result, the regional distribution and sub-cellular localization of opiate receptor sites in different tissues of animals were soon found out. The distribution of the opiate receptor in brain parallels the medially located paleospinothalamic and spinoreticular pathways which are thought to regulate affective components of pain response. It is obvious that further detailed studies on the regional variations in opiate receptor binding mechanisms may greatly elucidate the basic physiology of pain mechanism. On the other hand, sub-cellular localization studies amply demonstrate that opiate receptor binding is primarily localised in the synaptic membrane and in the vesicles, indicating thereby that morphine and other opiate drugs exert their action, just like the neurotransmitters and other psychotropic drugs, at the synaptic region level.

In Quest for Endogenous Ligand of Opiate Receptors

The next big achievement in this field of research is the search for identification of the endogenous material with opiate activity. Opiate drugs do not occur naturally in brain and other tissues ; it was therefore assumed that opiate receptors function somehow requiring some endogenous neurotransmitter like molecules, which are very common phenomena in synaptic neurotransmission processes. The isolation of opiate receptor-specific endogenous neurotransmitter molecules proved like the searching of needle in a haystack and three laboratories quite independently joined in this race. John Hughes, working in the laboratory of Hans Kosterlitz at the University of Aberdeen, Scotland, identified in 1975, a peptide material in the brains of pigs, cows, guineapigs, rats and rabbits that behaves exactly like morphine to inhibit contractions in smooth muscle preparations. Hughes named this material as "Enkephalin" which is a peptide containing 5 amino acids. Subsequent detailed analytical work on amino acid sequencing study by Dansyl Edman procedure and by mass spectrometry revealed that enkephalin pentapeptide may occur in two forms viz. methionine-enkephalin and leucine-enkephalin. The methionine-enkephalin molecule has the following sequence (a) H-Tyrosine-Glycine-Glycine-Phenylalanine-Methionine-OH (b) H-Tyrosine-Glycine-Glycine-Phenylalanine-Leucine-OH. Quite independently Terenins and Wahlstrom in Sweden (1974) and Pasternak, Goodman and Snyder at Baltimore, U. S. A. (1975) isolated morphine-like peptides from brain tissues, which also possess analgesic activity and binding ability with opiate receptor sites like morphine group of drugs. Like enkephalin, these morphine-like peptides, called "Endorphin" or endogenous morphine factors are also low molecular weight peptides, although their molecular weights are not the same as that of enkephalin. At present it cannot be decided whether the morphine like peptides are identical with natural enkephalin, isolated by Hughes and his group. In view of the small size of enkephalin peptides, the chemical synthesis of these biologically active compounds have been easily achieved and the availability of synthetic enkephalin has widened the facilities for further research on the molecular mechanism of pain sensation in our body.

Physiological Role of Enkephalin

The physiological role and the mechanism of action of enkephalin in brain still remain to be elucidated by further research. Studies on the comparative distribution patterns of enkephalin and opiate receptors in different parts of human and monkey brains have revealed a remarkable parallelity between each other. Another important finding emerging from this distribution pattern is that both enkephalin and opiate receptors are generally localised in two important centres of brain, connected with perception of pain and emotional reactions. This may probably explain the two major effects viz., analgesia and euphoria, associated with the action of opiate drugs in general.

Although it is not certain whether there are other naturally occurring morphine-like peptides besides enkephalin in our brain, researches, for the time being, are more focussed on enkephalin molecule which may prove to be an "open sesame" approach to our understanding of pain mechanism. Kosterlitz and Hughes believe that normal brain does possess a pain suppressive system and enkephalin plays a big role in it. But how ? It is presumed that enkephalin molecules, which are synthesized and stored in nerve cells, are released near the selective synaptic regions which also shelter the specific opiate receptors. This is followed by interaction between opiate receptors and enkephalin. This interaction gives rise to the triggering of signals within morphine sensitive neurons which actually carry message for pain sensations in our body. There is also another view point that enkephalin simply modulates, like prostaglandin, the post-synaptic membrane regions in morphine sensitive neurons. Whatever may be the exact mechanism of its action, enkephalin may be assumed to control certain inhibitory mechanism in neurotransmission system and as a result pain sensation is suppressed. Many provocative questions, which still baffle our mind, arise in this connection. Is enkephalin an ideal pain relieving drug in the sense that it is free from any addiction or tolerance side effects which are the common harmful effects of opiate drugs in general ? Whether individual variation in pain sensitivity, which is a very common phenomenon, can be explained in terms of the bio-availability of enkephalin within the central nervous system ?

Molecular Basis of Addiction

For an understanding of tolerance and dependence phenomena associated with opiate drugs, painstaking research studies are going on at present on the interaction of endogenous enkephalin and exogenous opiates within the central nervous system.

It is thought that under normal conditions endogenous enkephalin plays the role of suppressor or inhibitor of pain sensation by combining with the opiate receptors. When one feels pain, during any ailments or fever, endogenous enkephalin is not active due to its low availability caused by decreased synthesis, or increased catabolic breakdown, and/or decreased release, or even due to decreased sensitivity of opiate receptor site. Each of these factors may be involved when we feel pain in our body. If exogenous opiate drugs are administered at this time. the opiate drugs at once combine with opiate receptors and start doing the same function done by endogenous enkephalin. Pain is suppressed in this case also but there is a big change ; the control mechanism is switched from the endogenous enkephalin to the exogenous opiate drugs—the opiate receptors get adapted to the opiate drugs and only respond to these drugs, and not to endogenous enkephalin for the time being. This may be a negative feed back effect shown by opiate receptor—or in more popular terms we may state that opiate receptor molecules suffer a memory loss of enkephalin. Thus the central nervous system becomes wholly dependent on the supply of exogenously supplied opiate drugs for maintaining the inhibitory mechanism in pain suppression. When the opiate drugs are suddenly withdrawn, the inhibitory mechanism suddenly gets out of gear and the endogenous enkephalin, which may be available in the system, becomes inactive because the opiate receptors have not yet regained their sensitivity to endogenous enkephalin. This may explain the so-called withdrawal phenomena commonly observed with opiate drugs.

Neurobiochemists and molecular pharmacologists are all excited over this new exciting molecule called enkephalin, which holds the key to our understanding and finally the conquest of pain. Futher researches on enkephalin will lead us to a goal long sought after by the pharmacologists—the design of ideal pain killing drug—maintaining the potency but without the addictive side effects.

Inventions in Semiconductor Electronics*

B. R. NAG

Centre of Advanced Study in Radio Physics and Electronics, Calcutta University.

The first semiconductor electronic device was invented in 1904 by Acharya J. C. Bose. It was essentially a galena crystal with a point contact and was used for the detection of electromagnetic radiation. Very little, however, happened in this field afterwards and no significant invention was made till 1948. In that year Bardeen and Brattain announced the invention of transistor. In the era that followed this invention a new semiconductor device has been invented almost every year. Junction transistor, field-effect transistor, solar cell, silicon-controlled rectifier, tunnel diode, Gunn diode, Read diode, Impatt, Trapatt, Baritt, light-emitting diode, laser diode, heterostructure laser and integrated circuits are some of these important inventions. The study of the history of these inventions is very relevant to the present controversy about pure and applied research. The objective of this article is to trace the story of development of some of these devices with the purpose of finding out how the particular device came to be invented.

We shall outline the story of field-effect transistor, diode laser and Gunn diode. The basic idea of a field-effect transistor may be considered very elementary. The charge carriers in a conductor or a semiconductor being mobile, when a sample of these materials is subjected to an electric field, the carriers move under the action of the field towards its surface. Space charge is built due to the collection of these carriers and the resulting field cancels the applied field to produce the steady state. The excess charge carriers collecting at the surface should alter the conductivity of the surface layer. This layer would be very thin in a conductor but in a semiconductor the thickness of the layer may be appreciable as the carrier concentration is low. The current between two contact points on the surface of a semiconductor should therefore be controllable by a transverse electric field and an active semiconductor device may be thereby realised. This is essentially how a field-effect transistor works. The idea was patented by Lilienfeld as early as in 1925. The early attempts to realise a transistor were also concentrated on this idea. But it did not work. The current in the surface layer could not be controlled significantly by the transverse field. The reason for this failure of the promising idea was the ignorance of the physics of semiconductor surface. The failure was explained by Bardeen to be due to the

---

***Study supported by the Jawaharlal Nehru Memorial Fund.**

presence of the surface states which trap the collected carriers and make them immobile. Hence, even though a charge layer is produced, the current through the layer is not significantly altered. After the realisation of this difficulty the inventors of the transistor followed a different track. But even after the transistor was invented the importance of realising the field-effect device did not die out as its expected high input impedance could be advantageous in some applications. Researches for the realisation of a field-effect transistor were therefore carried out with undiminished zeal. The physics of semiconductor surfaces was studied very intensively. Efforts were directed towards understanding the nature of the surface state and of the factors which controlled the concentration of these states. These studies produced new results and Dacey and Ross realised the field-effect transistor in 1953 using an idea published by Shockley in 1950. The effect of the surface states was controlled in this device by growing a layer of opposite type on the surface of the semiconductor sample and the current was controlled by controlling the thickness of the depletion layer between the surface layer and the bulk. In a way the problem of the surface states was by-passed in this device. A solution to the problem of the surface layer was, however, obtained when it was discovered in 1959 by Atalla that the concentration of the surface states could be very much reduced by growing an oxide layer on the silicon surface. This discovery is exploited in metal-oxide field-effect transistor and the related devices. In these devices, instead of growing a layer of opposite type, an oxide layer is grown and the control field is applied across this layer. These field-effect transistors are gradually replacing the conventional transistors in different areas of modern electronics. The lesson that we learn from the story of this invention is that realisation of a practical device often requires study of an aspect of physics which may not appear important beforehand. Had the physics of semiconductor surface been known before attempts were made to realise the device, the first attempt would have been successful. Some of the transistors, which are becoming obsolete with the emergence of new varieties of field-effect transistors, might not also have been invented.

The sequence of events leading to the development of the diode laser is just opposite to that of the field-effect transistor. In this case the researches on physics preceded the technology. Luminescence had been one of the important areas of study for a long time. Junction diodes were known to emit radiation and were being used as light-emitting diodes. The invention of the transistor had also kindled interest in the recombination processes in semiconductors. The recombination mechanisms determined the life time of injected carriers in a transistor and the high frequency performance of a transistor is inherently dependent on this life time. The physics of the recombination of injected carriers in different semiconductors had therefore been studied extensively. A vast wealth of experimental results were thereby available about the recombination phenomenon. The theory of the recombination processes was also very well developed. The physical processes causing the absorption of light in semiconductors were also thoroughly studied. Through these studies it became possible to predict the amount of light that might be produced when a particular concentration of minority carriers were injected and also to calculate what fraction of this light would be reabsorbed. One could thus work out almost exactly the required carrier concentration to produce stimulated emission in a particular semiconducting material. In this background Dumke did his calculations in 1962 and suggested the material and the injected carrier density that should make a light emitting diode a laser. Experiments by producing the suggested conditions turned out to be immediately successful. Six months after the publication of Dumke's paper the invention of the diode laser was reported almost simultaneously by three groups of workers in 1963. The lesson in this case is that when the physics is properly studied an idea is very likely to work. Since physics of recombination of carriers and absorption of light was that well studied, the required conditions for a lasing diode could be produced and the laser diode realised in the very first attempt.

The story of the invention of the Gunn diodes is quite different from that of the other two related above. As early as in 1930's, theoreticians had predicted that the conductivity of ionized gases should change at high fields even when the concentration of free electrons and the temperature of the neutral gas particles are not altered by the field. It was realised with the development of the theory of electron transport in semiconductors that the prediction should be equally applicable to conductors or semiconductors. The prediction contradicted the time-old Ohm's law and therefore evoked interest in physicists. In 1951 Shockley and Ryder carried out the experiments producing the required conditions and found that, as predicted, the conductivity decreased at high fields even though the lattice temperature and the carrier concentration were kept constant. They derived satisfaction out of the experiment as physicists and concluded that Ohm's law was an approximate law like the Hooke's law or the Newton's law. The observed violation of the Ohm's law could thus be considered as a triumph of the theory of transport. At that time no one could predict that the study of the phenomenon might yield a useful practical device.

The physics of the phenomenon of non-ohmic or the so-called hot electron transport, however, continued to be interesting to a group of workers. The various aspects of the phenomenon were studied in the subsequent years. In the beginning, elemental semiconductors were studied and then compound semiconductors such as indium antimonide and indium arsenide were also studied. The experimental results emerging from these studies also required for their clarification the development of the theory of hot-electron transport. Some peculiarities in the characteristics of germanium led to the idea of electron transfer from one valley to another valley in the energy-momentum space. The physics of electron transfer in a hot-electron field was therefore developed. Through such studies it was predicted independently by Ridley and Watkins and Hilsum in 1961 that the phenomenon might give rise to negative differential conductivity in the bulk characteristics of a semiconductor. They suggested germanium-silicon alloy and gallium arsenide as some of the suitable materials for observing this effect. Gunn, on the other hand, had been experimenting in the field of hot electron transport almost from the days of the first experiment. It was natural for him to look into the characteristics of gallium arsenide, since elemental and more known III-V compounds had already been studied. In his experiments he came across the phenomenon, now known as Gunn effect, that beyond a certain threshold field the current through a piece of gallium arsenide becomes unstable. It was not immediately realised that he had been observing the already predicted electron-transfer effect and, in fact, one year of arguments was required to establish that the Gunn effect was a result of transfer of electrons from the central valley to the higher satellite valleys. However, the controversies were short lived and the understanding of the mechanism of this effect helped in the development of devices exploiting the effect. These devices, known as Gunn diodes or transferred electron devices are now widely used for microwave generation and amplification. We thus find that in the case of Gunn diodes the invention is a chance product of experiments in physics. Experiments conceived to verify a theoretical prediction of physics brought to light a new phenomenon which turned out to be useful for practical devices.

The history of the invention of these three important semiconductor devices thus leads us to some important conclusions. We find that inventions are made following different routes and that there is not a single route to a new discovery. Sometimes an invention results from the pursuit of research on an aspect of pure physics, sometimes an invention is conceived from the well-known physics of a phenomenon and sometimes even a well conceived idea fails for the lack of knowledge of the relevant physics and this knowledge has to be acquired for the practical realisation of the idea. We also find that the semiconductor electronics is intimately dependent on the physics of semiconductors. It is perhaps due to our rudimentary knowledge of semiconductor physics in the years preceding the invention of transistors, that no significant new semiconductor device was produced after the invention of the point-contact detector. Any research which promises to unravel some mystery of semiconducting materials should therefore be considered relevant to semiconductor electronics. It is by studying the physics of semiconductors, be it relevant or irrelevant to a device, that we may aspire to make an invention in this field.

Some Conjectures and Results on the Critical Parameters of a Lennard-Jones Gas

CHANCHAL KUMAR MAJUMDAR
Department of Physics
University College of Science, Calcutta—9

The critical phenomena in a gas liquid transition were discovered in carbon dioxide by Andrews (1869). The work raised several important questions. They have been discussed ever since and not completely answered. The general question was a qualitative understanding of the condensation phenomenon : why do the gas molecules congregate in the liquid phase at all ? More quantitatively, can we calculate the isotherms that Andrews observed ? Can we compute the critical parameters, the critical temperature T_c, the critical pressure p_c and the critical density ρ_c ?

- 1 -

It is well known that van der Waals made a remarkable contribution by modifying the perfect gas equation and proposing a two parameter equation of state

$$\left(p + \frac{a}{V^2}\right)(V—b) = Nk_BT = RT \qquad \ldots \qquad (1)$$

Here p, V, T stand for the pressure, volume and temperature of one gm. mol. of a gas, N is the Avogadro number, k_B the Boltzmann constant and R the gas constant for one gm mol., a and b are the van der Waals parameters. The parameter b is the excluded volume that arises on account of the finite size of the molecules. The parameter a represents the effect of the sphere of attraction around each moecule. The molecules of van der Waals are not perfect point particles without mutual attraction but have a short range repulsion and a weak long range attraction. The isotherms calculated from Eq. (1) are fairly realistic but show, below the critical temperature, an unstable region, which is usually obliterated by the well-known Maxwell construction. On the whole a correct qualitative picture of condensation is obtained here through the interplay of short range repulsion and long range attraction. A detailed physical understanding of the van der Waals-type equation can be obtained from the work of Kac, Uhlenbeck and Hemmer[1] on a model due to Kac.

Following van der Waals, other two parameter equations of state have been proposed[2]. For example :

Dieterici

$$p = RT(V-b)^{-1} \exp(-a/RTV) \qquad \ldots \quad (2)$$

Berthelot

$$\left(p + \frac{a}{V^2 T}\right)(V-b) = RT \qquad \ldots \quad (3)$$

Saha and Bose[3]

$$p = -\frac{RT}{2b} \ln\left(1 - \frac{2b}{V}\right) \exp(-a/RTV) \qquad \ldots \quad (4)$$

In Table I we show the predictions about the critical parameters from these equations. Also included is the ratio $p_c V_c/RT_c$ which is free of the parameters a and b. Experimental results on simple gases agree well with this ratio of Dieterici or Saha and Bose.

TABLE 1 : *Critical Parameters*[3,7]

	vdW	*D*	*B*	*SB*
T_c	$8a/27Rb$	$a/4Rb$	$\sqrt{(8a/27Rb)}$	$a/2e\,Rb$
p_c	$a/27b^2$	$a/4e^2 b^2$	$\sqrt{(aR/216b^3)}$	$ae^{-(e-1)}/4b^2$
V_c	$3b$	$2b$	$3b$	$2be/(e-1)$
$p_c V_c/RT_c$	$3/8$ $=0.375$	$2/e^2$ $=0.29$	$3/8$ $=0.375$	$e.e^{-(e-1)}/(e-1)$ $=0.28$

It is perhaps remarkable that all these equations give the same shape of the critical isotherm

$$p-p_c = \frac{3}{2}\, ab\, (\rho-\rho_c)^3 \quad (vdW)$$

$$p-p_c = \frac{4}{3}\, \frac{ab}{e^2}\, (\rho-\rho_c)^3 \quad (D)$$

$$p-p_c = \frac{3}{2}\left(\frac{27}{8}\, Rab^3\right)^{\frac{1}{2}} (\rho-\rho_c)^3 \quad (B)$$

$$p-p_c = \frac{1}{3}\, e^{3-e}\, ab(\rho-\rho_c)^3 \quad (SB) \qquad \ldots \quad (5)$$

This means that the shape index δ of the critcal isotherm, defined by the relation

$$p-p_c \propto \mathrm{sgn}(\rho-\rho_c)\, |\rho-\rho_c|^{\delta} \qquad \ldots \quad (6)$$

is always 3. In fact, it is not accidental and is a result of the underlying analyticity assumption of the approach of the equation of state. The cubic form is a consequence of the assumption that the critical point is non-singular and that one can expand various quantities in power series around it[4] .

Viewed from the fundamental dynamical stand point, the parameters a and b of the equations of state are not well defined. How are they related to the interaction potential between the molecules? One could say that 'b' is related to the hard-core radius (provided there is some thing like a hard core in the potential) but the parameter 'a' cannot be identified with anything directly. So given any intermolecular potential, say the 6-12 Lennard-Jones potential, the critical parameters cannot be immediately computed directly from a and b. Empirically, a and b are not really constants ; to fit with the isotherms they are made temperature dependent. Experimental evidences of recent years indicate that the critical point is a singular point, and the assumption of holomorphy at T_C is false[5]. Of course exact theoretical solutions of models also demonstrate this.

- 3 -

Given the intermolecular potential $v(r)$, say the 6-12 Lennard-Jones potential

$$v(r) = 4\varepsilon\,[(\sigma/r)^{12} - (\sigma/r)^{6}] \qquad \ldots \quad (7)$$

the pressure p and density ρ of a gas at a temperature T are given by the fugacity expansions[6]

$$p/k_BT = \sum_{l=1}^{\infty} b_l z^l \qquad \ldots \quad (8)$$

$$\rho = \sum_{l=1}^{\infty} l b_l\, z^l \qquad \ldots \quad (9)$$

z is the fugacity, related to the chemical potential μ by $z = \exp(\mu/k_BT)$. b_l's are the irreducible cluster integrals[6]. Eliminating the fugacity, we get the series

$$p/k_BT = \rho\left[1 + \sum_{m=2}^{\infty} B_m\, \rho^{m-1}\right] \qquad \ldots \quad (10)$$

B_m's are related to the contribution of stars[6]. They are also related to the virial coefficients. By writing $\rho = N/V$, we have

$$\frac{pV}{Nk_BT} = 1 + \frac{B_2N}{V} + \frac{B_3N^2}{V^2} + \ldots\ldots \qquad \ldots \quad (11)$$

so that B_2N, B_3N^2, ... etc are the second, third, etc. virial coefficients, respectively. For the Lennard-Jones potential (7) four B_m, $m = 2$ to 5, have been computed by Barker, Leonard and Pompe[8]. We want to indicate a method of computing the critical parameters directly and the shape index δ from this information. One ought to emphasize that it is a part of the problem to show from Eq (8), (9) and (10) that the critical isotherm has indeed the form given by Eq. (6).

It is easy to see that the van der Waals equation can be put in the form of Eq. (11).

$$\frac{pV}{Nk_BT} = 1 + \frac{1}{V}\left(b - \frac{a}{RT}\right) + \frac{b^2}{V^2} + \frac{b^3}{V^3} + \ldots \qquad \ldots \quad (12)$$

The second virial coefficient has a zero at the temperature $T_c = a/Rb$. This is the Boyle temperature. The higher virial coefficients are of a particular simple from $B_l \sim b^{l-1} (l \geqslant 3)$. Also note that the critical point $\rho_c = (1/3b)$ lies well within the radius of convergence $\rho = b$. This makes the critical point a point of regularity.

One could study each two parameter equation of state in the same fashion. It will be enough for our purpose to note that the virial coefficients for the Dieterici equation, the most successful equation, are polynomials in a and b, and are rational functions of temperature, the only pole in temperature being $T = 0$.

- 4 -

The method we adopt to calculate the critical parameters and find the isotherm of Eq. (10) is to exploit the analogy with the Ising model[9]. It is well-known that the critical point is a singular point in this case. So no analyticity assumption is made. Let us briefly look at the results on the Ising model which will be of use.

The Ising Hamiltonian with exchange constant J and external field H is

$$H = -J \sum_{\langle i,j \rangle} \sigma_i \sigma_j - mH \sum_i \sigma_i \qquad \dots \quad (12)$$

Each $\sigma_i = \pm 1$; m is the moment per spin. The sum goes over i and j, where these are nearest neighbours. Analogous to (8) and (9), we have the high field expansion of the free energy $F(T, H)$ for a lattice with coordination number q :

$$F/k_BT = -mH/k_BT - \tfrac{1}{2}qJ/k_BT - \sum_{l=1}^{\infty} L_l(u)\, \mu^l \qquad \dots \quad (13)$$

where we define

$$u = \exp(-4J/k_BT) \; ; \quad \mu = \exp(-2mH/k_B T) \qquad \dots \quad (14)$$

$L_l(u)$ are the high field polynomials, computed with enormous effort and skill by Sykes and his collaborators[10]. It has been shown [11,12] that (*i*) all the polynomials $L_l(u)$ are positive in $0 < u < u_c$ with $u_c = \exp(-4J/k_BT_c)$, (*ii*) the first real zero $u_l^{(1)}$ of L_l to the right of the origin tends to u_c, thereby locating the critical point as a limit point, and (*iii*) asymptotically, $L(u_c) \approx c_0 l^{-s}$, with $s \approx 2.20$ in three dimensions. The first two points are connected to the Yang-Lee theorems [13] on the Ising model and are essentially rigorous. The last feature enables one to show that the singular part of the free energy $F(T_c, H)$ is proportional to H^{s-1}. Hence the shape of the critical magnetization isotherm and its shape index δ given by $H \propto M^{\delta}$ can be calculated.

We shall pattern our calculation on the lines of that of the Ising model[14]. Note that the fugacity has exactly the form of the external field variable of Eq. (14) of the Ising model. We study the irreducible cluster integrals as a function of the variable $u = \exp(\varepsilon/k_BT)$, where ε is the same as in eq. (7). This is similar to the exchange variable of Eq. (14). We then find, within the limitations set by our numerical method, that the fugacity series has properties closely parallel to those found for the Ising model and listed above. The only novel feature is the presence of two series in fugacity, eqs. (8) and (9), in contrast with the single series (13) of the lattice problem. The interesting property that the high field polynomials at the critical temperature (more strictly at u_c) falls off in a power law is replaced by a slightly more general property, eq. (28), in the gas-liquid case.

- 5 -

To introduce quantities directly related to the parameters ε and σ appearing in the potential (7), it is conventional[7] to introduce the following quantities

$$b_0=\tfrac{2}{3}\pi\sigma^3, \qquad b=Nb_0=\tfrac{2}{3}N\pi\sigma^3 \qquad \dots \quad (15)$$

$$V^*=V/b, \qquad \rho^*=V^{*-1}=b_0\rho \qquad \dots \quad (16)$$

$$p^*=pb/N\varepsilon=pb_0/\varepsilon, \qquad T^*=k_BT/\varepsilon \qquad \dots \quad (17)$$

Now introducing

$$z^*=b_0z, \quad B_m^*=B_m/b_0^{m-1}, \quad b_l^*=b_l/b_0^{l-1} \qquad \dots \quad (18)$$

we get the expansions (10), (8) and (9) in the forms, respectively,

$$p^*/T^*=\rho^*\left[1+\sum_{m=2}^{\infty}B_m^*\,\rho^{*m-1}\right] \qquad \dots \quad (19)$$

$$p^*/T^*=\sum_{l=1}^{\infty}b_l^*\,z^{*l} \qquad \dots \quad (20$$

$$\rho^*=\sum_{l=1}^{\infty}l b_l^*\,z^{*l} \qquad \dots \quad (21)$$

Barker et al[8] have published B_m^* $(m=2$ to $5)$. We can calculate the irreducible cluster integrals b_l^*, $l=2$ to 5. b_l^* are then known as functions of T^*. If we define the variable

$$u=\exp(\varepsilon/k_BT)=\exp(1/T^*) \qquad \dots \quad (22)$$

the physical region of this variable is $1<u<\infty$. Fig. 1 shows the irreducible cluster integrals as function of u. For large u (low temperature) the cluster integrals are positive and that the right-most zero, which we denote by $u_l^{(1)}$, shifts to the right with l. The numerical values of $u_l^{(1)}$ are ($u_2^{(1)}$ corresponds to the Boyle temperature)

$$\begin{aligned} u_2^{(1)} &= 1.3399 \\ u_3^{(1)} &= 1.4892\pm0.0004 \\ u_4^{(1)} &= 1.5799\pm0.0003 \\ u_5^{(1)} &= 1.6480\pm0.0009 \end{aligned} \qquad \dots \quad (23)$$

Assume that as in the Ising model $u_l^{(1)}$ tends to a limit as $l \to \infty$. Trying a least squares fit

$$u_l^{(1)} = x_1 - x_2\, l^{-\eta} + x_3 l^{-2\eta},$$

we get

$$u_l^{(1)} = 2.179 - 1.328\, l^{-0.529} + 0.169\, (l^{-0.529})^2 \qquad \ldots \qquad (24)$$

Hence we get

$$u_c = 2.179, \ T_c^* = 1.28 \qquad \ldots \qquad (25)$$

Since we have only four zeros, this is the best we could do. Probably T_c^* is slightly less than 1.28.

We can now compute the quantities $b_l^*(u_c)$, $l = 1$ to 5. $b_1^* = 1$ by definition. We can in fact estimate $b_l^*(u_c)$ for $l = 6$ to 15, because B_2^* is very large, and makes the dominant contribution. We try a three parameter fit

$$b_l^*(u_c) = X_1^{l-1}\left[\frac{1+X_2}{l^s} - \frac{X_2}{l^{2s}}\right] \qquad \ldots \qquad (26)$$

The X_1 term is absent in the Ising case, as the radius of convergence in the μ-plane is unity. For the fugacity series, X_1 determines the radius of convergence. The power law in l^{-s} is suggested by the Ising result, and also by Groenveld's bounds[15] on the cluster integrals. The last term is fixed in such a way as to ensure $b_1^* = 1$. Eq. (26) is a non-linear fitting problem and requires a sophisticated computer programme developed by CERN, fortunately available to us.

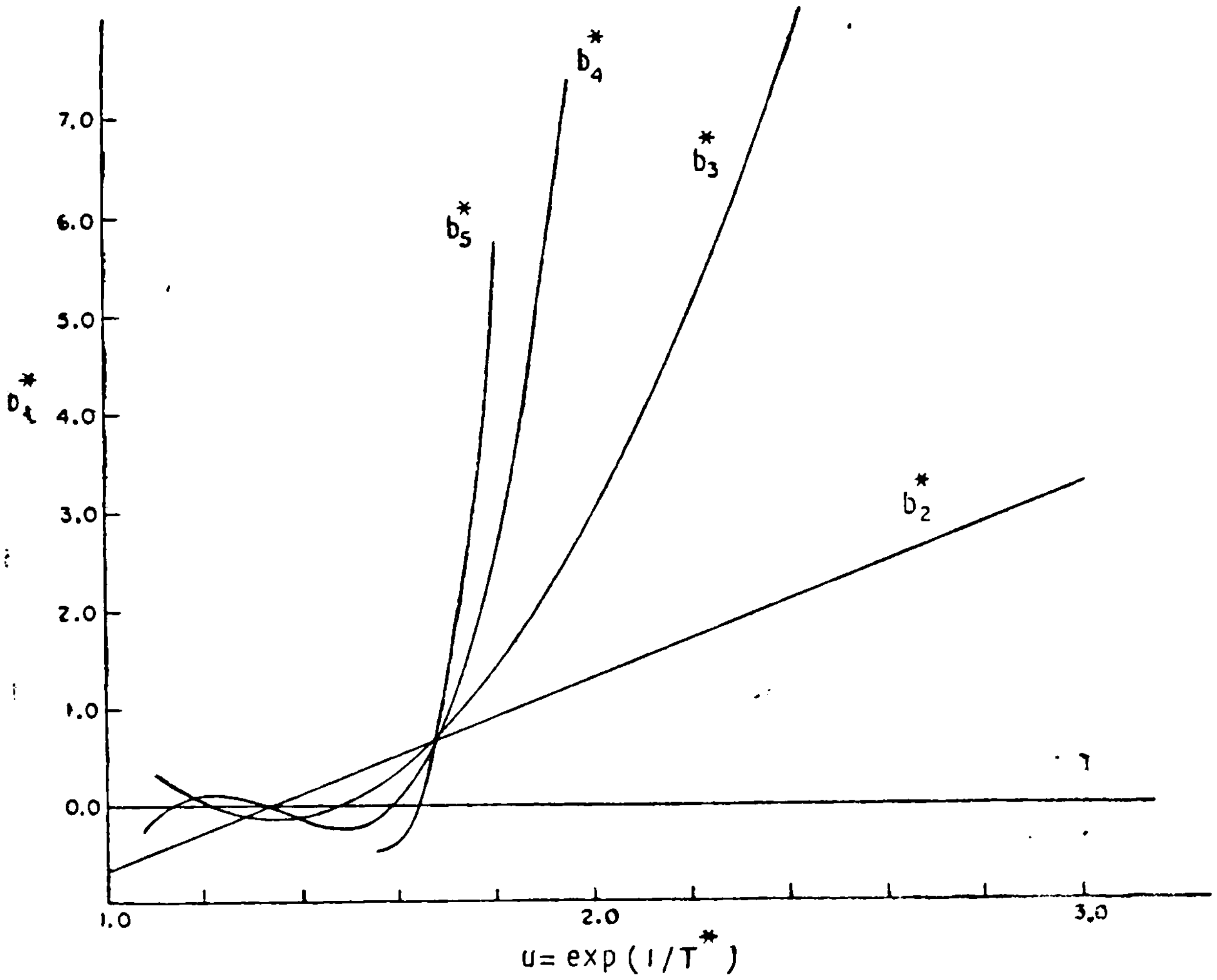


Fig. 1. The irreducible cluster integrals of the Lennard-Jones gas as functions of $u = \exp(1/T^*)$.

Using $T_c^* = 1.28$, the best fit is

$$b_l^*(u_c) = (7.6815)^{l-1}\left[\frac{1.00802}{l^{2.258}} - \frac{0.00802}{(l^{2.258})^2}\right] \qquad \ldots \quad (27)$$

The value of s is very sensitive to T_c^* and, of course, limited in accuracy by the very few b_l^*'s we have.

As $l \to \infty$, the asymptotic behaviour of $b_l^*(u_c)$ is then

$$b_l^*(u_c) \sim C_0 z_c^{-l}/l^s \qquad \ldots \quad (28)$$

with

$$s = 2.258, \; z_c = 0.13018, \; C_0 = 0.13123 \qquad \ldots \quad (29)$$

Eqs. (20) and (21) become

$$p^*/T_c^* \approx C_0 \sum_l (z^*/z_c)^l/l^s \qquad \ldots \quad (30)$$

$$\rho^* \approx C_0 \sum_l (z^*/z_c)^l/l^{s-1} \qquad \ldots \quad (31)$$

Now let $z^* \to z_c$, the singularity of the critical point, which is the nearest real physical singularity as the coefficients are all positive[16]. Truesdell[17] has shown that when

$$\phi(x, s) = \sum_{n=1}^{\infty} \frac{x^n}{n^s} \qquad \ldots \quad (32)$$

with $s > 1$ we get asymptotically as $x \to 1-0$

$$\phi(x, s) = \Gamma(1-s)(-ln x)^{s-1} + \sum_{n=0}^{\infty} \frac{\zeta(s-n)}{n!} (l_n x)^n \qquad \ldots \quad (33)$$

Thus (31) gives

$$\rho^* = C_0\Gamma(2-s)[-ln(z^*/z_c)]^{s-2} + C_0\zeta(s-1) + \ldots \qquad \ldots \quad (34)$$

the higher terms are negligible. We get

$$\rho_c^* = C_0\zeta(s-1) = 0.562 \qquad \ldots \quad (35)$$

and

$$\begin{aligned} \rho_c^* - \rho^* &= -C_0\Gamma(2-s)\,[-ln(z^*/z_c)]^{s-2} \\ &= \frac{C_0(s-1)\pi}{\Gamma(s)\sin \pi s}\,[-ln(z^*/z_c)]^{s-2} \end{aligned} \qquad \ldots \quad (36)$$

The right-hand side is positive as we are approaching the critical density ρ_c^* from the low density side. Eq. (20) gives

$$\begin{aligned} p^*/T_c^* &= C_0\Gamma(1-s)\,[-ln(z^*/z_c)]^{s-1} + C_0\zeta(s) \\ &\quad - C_0\zeta(s-1)\,[-ln(z^*/z_c)] + \ldots \end{aligned} \qquad \ldots \quad (37)$$

Since $s > 1$, the first term is smaller than the last term kept. So putting

$$p_c^*/T_c^* = C_0\zeta(s) = 0.191, \; p_c^* = 0.240 \qquad \ldots \quad (38)$$

we get

$$(p_c^* - p^*)/T_c^* = C_0\zeta(s-1)\,[-ln(z^*/z_c)] \qquad \ldots \qquad (39)$$

Eliminating $-ln(z*/z_c)$ from (37), (39) we get the equation for the critical isotherm

$$(p_c^* - p^*)/T_c^* = C_0\zeta(s-1)\left[\frac{\Gamma(s)\sin\pi s}{\pi C_0(s-1)}\right]^{/(1s-2)}(\rho_c^* - \rho^*)^{1/(s-2)} \qquad \ldots \qquad (40)$$

We have $p_c^* > p^*$; which conforms to the correct sign in (6). Also

$$\delta = (s-2)^{-1} = 1/0.258 \simeq 3.9 \qquad \ldots \qquad (41)$$

The amplitude of the singularity is

$$T_c^*\,\rho_c^*\left[\frac{\Gamma(s)\sin\pi s}{\pi C_0(s-1)}\right]^{1/(s-2)} = 1.6 \qquad \ldots \qquad (42)$$

The universal ratio becomes

$$p_c^*/\rho_c^*\;T_c^* = \zeta(s)/\zeta(s-1) = 0.34 \qquad \ldots \qquad (43)$$

But δ is connected to s through (41) So we have the interesting relation

$$p_c^*/\rho_c^*\;T_c^* = \zeta(2+\delta^{-1})\,/\,\zeta\,(1+\delta^{-1}) \qquad \ldots \qquad (44)$$

If one accepts that the critical index δ is universal[18], the universality of the ratio $p_c^*/\rho_e^*\,T^*$ follows.

It might be pointed out that (35) and (39) imply that

$$p_c^* - p^* = \rho_c^*(\mu_c^* - \mu^*) \qquad \ldots \qquad (45)$$

μ^* being the reduced chemical potential measured in units of ε. (45) is actually a thermodynamic relation

$$\rho = (\partial p/\partial\mu)_T$$

used at T_c.

- 6 -

Table II shows the critical constants of the heavier rare gases and the Lennard-Jones parameters ε and σ. Our best values are $T_c^* = 1.28$, $p_c^* = 0.24$, $\rho_c^* = 0.56$ and $p_c^*/\rho_c^*\,T_c^* = 0.34$. The agreement is good, and presents strong support for eq. (28).

TABLE II : *Critical constants and Lennard-Jones parameters of the heavier rare gases.*

Gas	$T_c^{*\,a}$	$p_c^{*\,a}$	$\rho_c^{*\,a}$	$p_c^*/\rho_c^*\,T_c^*$	ε/k^b	σ^b
					°K	°A
Ne	1.28	0.23	0.63	0.296	34.9	2.78
A	1.26	0.24	0.66	0.291	119.8	3.405
Kr	1.22	0.22	0.64	0.281	171	3.60
Xe	1.31	0.28	0.73	0.293	221	4.10

(*a*) Critical data from G. A. Cook, *Argon, Helium, and the Rare Gases.* (Interscience, 1961) Vol. 1, p 392.

(*b*) Reference 7.

The index δ for Argon was estimated by Widom and Rice[19] to be 4.2 ± 0.2. Vicentini-Missoni et al[20] found $\delta = 4\ 6 \pm 0.5$ or 4.6 ± 0.1 for Xenon. Our value is 3.9 and is a little too low. This number is definitely lower than the corresponding number $\delta = 5$ for the Ising model. One may also recall that the second order ε-expansion in the renormalization group approach[18] gives $\delta = 4$, 4.2. The critical amplitude (42) seems not to have been measured.

- 7 -

The agreement with the experimental data and the derivation of the correct form (40) of the critical isotherm suggest that the following conjectures are true :

(1) All the irreducible cluster integrals of the Lennard-Jones gas are positive at sufficiently low temperatures. The critical point is the real physical singularity that determines the convergence of the fugacity series. The critical temperature, or rather the quantity u_c, is determined as the limit of the leading zero of the irreducible cluster integrals[21].

(2) The asymptotic behaviour at T_c of the irreducible cluster integrals of the Lennard-Jones case is

$$b_l^* (u_c) \sim C_0 \, z_c^{-l} / l^s$$

with $s \approx 2.25$.

References

1. M. Kac, G. E. Uhlenbeck and P. C. Hemmer, J. Math. Phys., 4, 216 (1963).
2. M. N. Saha and B. N. Srivastava, '*A Treatise on Heat*' (The Indian Press, Allahabad. and Calcutta, 1958) 4th edition, Chap. 11
3. M. N. Saha and S. N. Bose, Phil. Mag. Sr VI, 36, 199 (1918), Collected Papers of M. N. Saha, p. 14 (edited by S. Chatterjee, C S I R, New Delhi, 1969).
4. M. E. Fisher, J. Math. Phys., 5, 944 (1964).
5. M. E. Fisher, Rep. Prog. Phys., 30, 615 (1967).
   P. Hiller, Rep. Prog. Phys., 30 (1967).
6. G. E. Uhlenbeck and G. W. Ford, *Studies in Statistical Mechanics*.
7. J. O. Hirschfelder, L. F. Curtiss and R. B. Bird, *Molecular Theory of Gases and Liquids* (John Wiley and Sons, Inc., New York, 1954).
8. J. Barker, P. J. Leonard and A. Pompe, J. Chem. Phys., 44, 4206 (1966).
9. C. Domb, Adv. Phys., 9, 149 (1960) and Adv. Phys., 9, 245 (1960)
10. M. F. Sykes, J. W. Essam and D. S. Gaunt, J. Math. Phys., 6, 283 (1965).
    M. F. Sykes, D. S. Gaunt, S. R. Mtatingly, J. W. Essam and C. J. Elliott, J. Math Phys., 14, 1066 (1973)
    M. F. Sykes, D. S. Gaunt, J. W. Essam, B. R. Heap and S. R. Mattingly, J. Phys., A 6, 1498 (1973).
    M. F. Sykes, S. McKenzie, M.G. Watts and D. S. Gaunt, J. Phys., A 8, 1461 (1975).
    M. F. Sykes, M. G. Watts and D. S. Gaunt, J. Phys., A 8, 1448 (1975).
11. C. K. Majumdar., Phys. Rev. B 10, 2857 (1974)

12. C. K. Majumder, Soluble Models in Statistical Mechanics, in "Statistical Physics", a Supplement to the Journal of the Indian Institute of Science, Bangalore (1975) pp. 1-50

13. C.N. Yang and T.D. Lee., Phys. Rev., 87, 404 (1952), T.D. Lee and C.N. Yang., Phys., Rev. 87, 410(1952).

14. I. Rama Rao and C. K. Majumder, presented in the Nuclear Physics and Solid State Physics Symposium, Calcutta (1975).

15. J. Groenveld, Phys. Lett., 3, 50 (1962); See also D. Ruelle., *Statistical Mechanics* (Benjamin, New York 1970) pp. 83—86 on the convergence of the virial series.

16. E. C. Titchmarsh, Theory of Functions (Oxford, Second Edition, 1939) p. 214.

17. C. Truesdell., Ann. Math., 46, 144 (1946).

18. The discussion of the Universality is found in K. G. Wilson and J. Kogut, Physics Reports, 126, 74 (1974) and M. E. Fisher, Rev. Mod. Phys,, 46, 597 (1974).

19. B. Widom and O. K. Rice., J. Chem. Phys,. 23, 1250 (1955). A. F. Grigor and W. A. Steele also reported $\delta = 4.3$ in 'Critical Properties of Argon' in *Physics and Chemistry of Liquids* (Gordon and Breach, 1968) vol. 1, pp. 129—139

20. M. Vincentini Missoni, R. I. Joseph, M. S. Green and J. M. H. Levert Sengers Phys. Rev. *B*1, 2312 (1970).

21. See also S. Katsura, Prog. Theor. Phys., 20, 192 (1958).

How "Elementary" Particles Proliferated

VISVAPRIYA MUKHERJI

Indian Institute of Technology, Kharagpur

In discussing the concept of elementarity in the analysis of matter Eddington said :

> "Our engrained form of thought is such that we shall not rest satisfied until we are able to represent all physical phenomena as an interplay of a vast number of structural units intrinsically alike. .. There is nothing in the external world which dictates this analysis into similar units, just as there is nothing in the irregular vibration of white light which dictates our analysis of it into monochromatic wave trains. The dictation comes from our own way of thought which will not accept as final any other form of solution of the problem presented by sensory experience."

It is pointless to quibble on whether this form of thought is native to Man or has been acquired by him through centuries of experience and observation. But this much is clear that when scholars of distant antiquity such as Democritus of Greece and Kaṇāda of India conceived of matter to be composed of basic, irreducible structural units (or atoms) moving randomly in the void, they depended on purely philosophical speculation without reference to any convincing empirical evidence. And when Gassendi, a French scholar of the 17th century, resurrected Democritean atomism in the face of the prevailing Aristotelean doctrine of matter being continuous and nondiscrete, and when Dalton established a rational science of chemistry on the basis of atomism (or corpuscular description of matter), there was "nothing in the external world which dictated this analysis into similar units". The *electron,* which was the first 'elementary' particle to be *discovered* (towards the end of the last century), was not universally accepted as a discrete irreducible unit of matter. Some schools of scientific thought were averse to the idea of the atomicity of matter and favoured the description of all phenomena in terms of continuously distributed matter and continuously acting laws. However, experimental investigations of diverse phenomena like Brownian motion, cathode rays, positive rays, radioactivity, x-rays, photoelectricity, blackbody radiation and hydrogen spectrum tipped the scale in favour of the concept of the discreteness of matter, charge as well as energy. Within the first decade of this century the electron was accepted as an elementary building block of matter, although no less a man than Oliver Lodge disagreed as late as 1925 in the following terms: "Electrons are evidently composed of ether, because whatever mass they may have is represented by the energy of their electric field, which is certainly an etherial phenomenon; and apart from this field they seem to have no other existence." However, such lone notes of dissent did not influence the general trend of opinions, which favoured the view that the electron existed as an elementary corpuscle.

When in 1911 Rutherford put forward his planetary model of the atom, he boldly pictured the orbital particles as electrons, but the elementary units of the central positive core (nucleus) were yet to be clearly defined and determined. Since positively charged alpha particles were found to be emitted from radioactive substances, physicists were tempted to consider alpha particles, i. e. helium-atom nuclei, as a kind of basic building stones of atomic nuclei, In 1920 Rutherford gave the name *proton* to the hydrogen nucleus—the incomparably heavier positive counterpart of the electron. But physicists took some time to be convinced that the proton was a basic unit constituting not only the alpha particle or helium nucleus but also all other atomic nuclei. Jensen refers (Nobel Lecture 1963) to a persistent warning from Schroedinger that one should not be tempted to look upon alpha particles as basic constituents of nuclei:

> "During the late twenties he [Schroedinger] chided the participants in a Berlin seminar for their lack of imagination. In his impulsive manner he said 'Just because you see alpha particles coming out of the nucleus, you should not necessarily conclude that inside they exist as such'. ...The situation that very little insight into nuclear structure could be gained from this oldest nuclear phenomena persisted for a long time."

It is worth mentioning here that as early as 1886 Crookes had predicted the existence of isotopes, and that in 1913 J. J. Thomson found the direct experimental evidence of the former's prediction by discovering two kinds of neon of atomic weight 20 and 22. Therefore, by 1913 it was conceptually necessary to explain why atoms of the same element (i. e. same nuclear charge) varied in weight. In April 1920 Harkins published a proposal that isotopy could be explained by imagining the existence, in the nucleus, of extra protons with closely packed neutralizing electrons. In June 1920 Rutherford also said in the Bakerian Lecture at the Royal Society of London:

> "Under some conditions...it may be possible for an electron to combine... closely with the hydrogen nucleus, forming a kind of *neutral doublet*. Such an atom would have very novel properties. Its external field would be practically zero, except very close to the nucleus, and in consequence it should be able to move freely through matter. Its presence would probably be difficult to detect by the spectroscope... On the other hand, it should enter readily the structure of atoms and may...unite with the nucleus...". (Italics mine).

This was the prediction of the *neutron,* which was discovered more than a decade later. But Rutherford's neutral doublet evidently meant a compound particle and not an elementary one. Anyhow, in the subsequent years the possible existence of an electrically neutral particle was sought, and in 1932 Chadwick discovered the neutron ; at that time he wrote :

> "We may suppose it to consist of a proton and an electron in close combination, the *neutron* discussed by Rutherford in his Bakerian Lecture of 1920. ...It is, of course, possible to suppose that the neutron may be an elementary particle."

Chadwick *hesitantly* suggested that the neutron was "elementary", but one thing had to be admitted that the assumption that the neutron was a proton plus an electron did not agree with empirical evidence, whereas the hypothesis that the neutron was an elementary constituent of atomic nuclei explained the empirical data very satisfactorily. It is interesting that Schroedinger, who had earlier chided the atomic physicists for considering the alpha particle to be a nuclear constituent, could not this time readily accept the neutron as an elementary building block of the nucleus. Soon, however, the neutron came to be universally accepted as an elementary particle, and one could consider that protons and neutrons were the fundamental structural units within the atomic nucleus. The initial conceptual uneasiness about the neutron's theoretical characterization was dispelled when Heisenberg and subsequently Cassen and Condon placed the proton and neutron on an equal footing (by postulating that they are *two* manifestations of *one* particle, the so-called "heavy particle" or *nucleon*) in terms of an abstract and non-visualizable quantum-physical quantity, the so-called *isotopic spin,* which assumes the value +1 for the 'proton state' and −1 for the 'neutron state' of the nucleon. Thus, this formal simplicity or conceptual economy was an important step towards classificatory unification of 'elementary' particles.—It should be mentioned here that till then physicists had been dealing with the *stable* particles, proton and electron. But with the addition of the *unstable* neutron, which decayed into a proton and an electron, physicists got accustomed to the idea that an 'elementary' particle could have a finite lifetime and that it could change into other 'elementary' particles.

With growing sophistication of quantum theory, the physics of elementary particles had been already drifting away from visualizable representations towards abstract and formal concepts with no analogues in classical physics. For example, the description that the "electron spins or rotates" is just a convenient visualization of the electron's behaviour which cannot really be described classically. And the subsequent history of particle physics is one of invoking a host of abstract non-classical quantities intended for establishing *unified* classification schemes of formal simplicity in the disconcerting *manifoldness* of so-called elementary particles.

Since scientists aim at reaching "intrinsically alike structural units" of matter, it is natural that there was some resistance to the introduction of the neutron as a new 'elementary' unit when already two accepted elementary particles—the proton and electron—could apparently explain the existence of different chemical elements and their isotopes. However, theorists ***had to*** accord elementarity to the neutron in order to account for all observed nuclear phenomena satisfactorily.

Before the discovery of the neutron, two other problems in particle physics baffled the theorists. These belied their unsophisticated hope of setting up a tidy classification scheme with a *very limited number* (if not "intrinsically alike") of structural units.—The first problem : In 1930 Dirac put forward his well-known electron theory which required that there should symmetrically exist an *exact* positive counterpart ('antiparticle') of the electron. Dirac tried to identify the predicted antiparticle with the known particle, proton ; but he felt unhappy about "the difficulty of the large mass difference". In fact, Hermann Weyl referred, in his contemporaneous book on quantum mechanics, to Dirac's theory as "Dirac's theory of the proton" and remarked : "However attractive this idea may seem at first, it is certainly impossible to hold without introducing other profound modifications to square our [i. e. Dirac's] theory with observed facts. Indeed, according to it the *mass* of a proton *should be the same* as the mass of an electron." (Italics mine). At that time they did not suspect that the proton was not the predicted antielectron and that the theory needed no modification. The actual need was to experimentally search for a new particle which would exhibit the *same mass* as the electron but an opposite charge. However, before Dirac's theory could be taken seriously by experimentalists, Anderson discovered (1932) in cosmic rays the real antielectron—the so-called *positron*—uninfluenced by Dirac's prediction. The Dirac theory was taken much more seriously only after Anderson's discovery. Once the theory proved convincing, this diversification of elementary particles did not disconcert the theorists ; rather, they considered it to be an indication of a fundamental symmetry of Nature that manifests itself in two charge conjugates for every particle. Evidently, it was theoretically expected that *antiprotons* or negative protons too might be found in cosmic rays, since all particles could exist in an antistate. As late as 1954 the antiproton could not be decisively detected in cosmic rays, but that very year the high-energy particle accelerator 'Bevatron', which had been purposely designed to produce antiprotons, came into operation, and the next year Segrè and others *did* discover the antiproton. Just as earlier there had been voices of dissent after the introduction of any new elementary particle, the existence of the antiproton too was not unreservedly believed in (before its discovery) by some dissenters as an obvious consequence of Dirac's theory. Alvarez said (Nobel Lecture 1968) :

> "In support of the non-obvious nature of the Segrè group's discovery of the antiproton I need only recall that one of the most distinguished high-energy physicists I know, who didn't believe that antiprotons could be produced, was obliged to settle a 500-dollar bet with a colleague who held the now universally accepted belief that all particles can exist in an antistate."

In contrast with such a scepticism about the antiproton, Dirac's bold imagination of the possible existence of an 'antiworld' composed of positrons and antiprotons is really remarkable. This he expressed as early as 1933 (i. e. just one year after the discovery of the positron) in his Nobel Lecture.* Thus the Dirac theory's conceptual expectation prompted physicists to accord elementarity to all observed as well as yet unobserved antiparticles, although their existence seemingly belied the earlier naive hope of framing a unified classification scheme with a *handful* of 'elementary' particles.—The second problem referred to above was this: The experimental data concerning beta-ray activity, i. e. emission of electrons from radioactive substances, needed a satisfactory theoretical explanation. The data seemed to violate the well-established law of energy conservation! In fact, of all persons, Bohr suggested that the energy of *some* emitted electrons or beta-rays was conserved, whereas for *some* emissions the law of conservation was violated; however, the total effect for many such emissions was a "statistical conservation of energy"! This fantasy was not taken seriously by physicists, especially because in 1924 Bohr had also upheld his theory of "statistical" conservation of energy in connexion with the explanation of the Compton scattering and almost immediately Bothe and Geiger experimentally invalidated that theory. Pauli "hit upon a desperate remedy to *save* the law of conservation of energy". In December 1930 he hypothesized the existence of a chargeless particle of evanescent mass "which exists in the nucleus" and is emitted "with each electron...in such a way that the sum of the energies" of this particle "and electron is constant". This idea of an almost massless neutral particle was received with great scepticism. But Fermi took Pauli's hypothesis seriously, named the elusive particle *neutrino* and built up in 1934 his convincing theory of beta-emission in terms of the so-called "electron-neutrino *field*" in analogy with the theory of emission of light quanta or electromagnetic *field* by an excited atom. He however did away with Pauli's assumption that the neutrino "existed in the nucleus" and conceived of the mechanism of concomitant *creation* of an electron and a neutrino when the nucleon passes from the proton state to the neutron state or vice versa. No sooner had the electron-neutrino theory been proposed by Fermi the notion of an 'antineutrino' was suggested. And immediately (1934) Bethe used the Fermi theory to show theoretically that a free antineutrino acting directly upon a proton would yield a neutron and a positron. But his prediction could not be tested with the techniques available at that time. About 20 years later Cowan and Reines discovered the antineutrino (supposed to be oozing out from a nuclear reactor) by experimentally substantiating its action upon the proton, as predicted by Bethe. Thus the elusive

---

* It is noteworthy that shortly after the discovery of the positron it was experimentally established that, as required by theory, an energy radiation like gamma ray can change into matter represented by an electron-positron twin (i. e. particle-antiparticle pair) and that if a slow electron and positron meet, they would be *annihilated* as material particles resulting in the production of an energy radiation.

particle together with its antiparticle, which ***had to*** be introduced ***to save*** the law of energy conservation, joined the proliferating group of 'elementary' particles.

The moment Fermi's theory offered, in 1934, a convincing description of beta-decay, Heisenberg was the first to suggest that the force, which held the protons and neutrons together inside the nucleus, might be due to the shuttling of an electron-neutrino pair between two nucleons. And this explanation of the nuclear force was seriously pursued. But the calculated force was found to be about 10^{14} times weaker than the empirical value. Although physicists were "very reluctant to give up" the "general idea of a connexion between beta-emission and nuclear forces" (as Bethe stated in 1936), they ***had to*** grope for an alternative mechanism for the nuclear force. This pointed to the need of introducing a new particle-conveyer of the nuclear force. In 1935 the Japanese physicist Yukawa boldly postulated the existence of a new particle (christened later by Anderson as ***mesotron*** and then by Bhabha as ***meson***) of mass about 200 times the electron's mass, which would satisfactorily account for the nuclear force. As usual there was an initial reluctance among theorists to accept a new particle. In early 1937 Bohr visited Japan when Yukawa talked to him about the meson theory, but Bohr asked "Why do you want to create such a new particle ?" However, soon Anderson, the American experimentalist who had discovered the positron, announced the detection of a new charged particle of mass about 200 times that of the electron in cosmic rays, completely unaware of Yukawa's prediction. Physicists now considered this to be identical with the predicted meson and took Yukawa's theory seriously. But for the whole decade subsequent to this discovery they felt baffled by the disagreement of some properties of the observed meson with the corresponding properties of the predicted meson, and the theorists attempted to reconcile the theory with the observed properties of the cosmic-ray meson till 1946 when Marshak in USA and Sakata in Japan independently felt it necessary to assume that the observed meson was not the Yukawa meson but was its decay product. The theory based on nuclear data demanded that the Yukawa meson must interact "strongly" with the nucleon, but an Italian group of experimentalists, Conversi et al., decisively showed (1946) that the cosmic-ray meson interacted "weakly" with the nucleon, just as the electron and neutrino did in the case of beta emission. This meant that the predicted (Yukawa) meson was yet to be discovered. In 1947 Powell discovered the Yukawa meson which he named the ***pi***-meson or ***pion***, and its decay product was named the ***mu***-meson or ***muon***. The latter was identified with the cosmic-ray meson that had baffled the theorists till then. So two more particles were added to the list of 'elementary' particles.—It should be mentioned here that as early as 1938 Kemmer postulated the existence of a ***neutral*** meson which ***had to*** be invoked for explaining the nuclear bond between two protons or two neutrons just as Yukawa had to introduce a charged meson for describing the bond between a proton and a neutron. As usual there were dissenters who felt reluctant to recognize "the existence of unobserved neutral mesons" which "is not indispensable to a theory of nuclear forces" (Marshak in 1940). But with the discovery of the pion the theorists got over their reluctance to recognize "unobserved" particles, especially those needed to theoretically account for all observed atomic and nuclear phenomena satisfactorily. So the neutral pion was searched for and discovered in 1950. Thus the pion family was filled out with a positive, a negative and a neutral particle. The study of the charged pions became easier, because these were found to be copiously produced (1948) in Lawrence's 184-inch cyclotron, and McMillan's 300-MeV synchrotron could be used by the experimentalists for studying the neutral pion.

The elementary particles, electron, neutrino, pion, proton, neutron with corresponding antistates and neutral particles as well as the light quantum (photon) *had to* be introduced for explaining all atomic and nuclear phenomena. But the muon does not belong to that category. It happens to exist but is not pressingly needed for interpreting ordinary atomic and nuclear phenomena. Thus it appears to be a 'superfluous' particle from the viewpoint of ordinary atomic and nuclear physics. However, it has been gradually felt since 1949 that the muon and electron not only belong to one class, they may be intrinsically the same particle, the former being a "higher state" of the latter ; nevertheless the great mass difference between them still baffles the theorists. —In the wake of the discovery of the pion, came a deluge of 'superfluous' particles which greatly disconcerted the theorists. From 1947 onwards, started arriving the unstable particles : V-, tau-, theta-, sigma- and xi-particle and a host of other particles, all of which proved to be "strongly interacting" among themselves. Thus strongly interacting particles began to proliferate, whereas the "weakly interacting" particles remained limited in number to only three : the muon, electron and neutrino. The theorists felt that it was necessary to bring all strongly interacting (*SI* for short) particles including the "new unstable particles" under a unified classification scheme, and accordingly in mid-1953 the participants of the Cosmic-Ray Congress at Bagnères-de-Bigorre, France, groped for it.

The theorists again encountered some incomprehensible problems. One problem was that the V-particle (christened as the lambda-particle at the Bagnères Congress) was found to be created very quickly which meant that it was a ***strong interaction*** or SI ; but it was found to decay slowly which meant that it was a ***weak interaction*** or WI. The problem now was to solve the puzzle of a very slowly decaying particle created by a very quick process. Pais proposed (1952) a solution of this puzzle in terms of the creation of a theta-particle concomitant with that of the lambda-particle —the so-called "associated production". The newly invented (1952) bubble chamber readily demonstrated the occurrence of this process.

It was realized that the associated production required the invocation of a new 'conservation' law. We know that the strict and universal validity of the laws of energy conservation, momentum conservation and electric-charge conservation have been well understood and accepted. Later, however it was felt necessary to invoke new conservation principles of limited validity such as those of the so-called *isotopic spin*, *baryon number*, etc. for describing the behaviour of the multiplying SI-particles. Now, in order to explain the "curious behaviour" of the "strange" particles, lambda and theta, Gell-Mann and Nishijima realized (1953) independently the need of introducing a new quantum-physical quantity *strangeness*, which is selectively conserved in strong interactions and electromagnetic interactions but not in weak interactions. Despite the selective validity of this phenomenological law, it successfully predicted the existence of unobserved particles.

Another baffling problem was the well-known "tau-theta puzzle". Until 1956 the physical quantity *parity* (which may be crudely understood as "mirror symmetry") was believed to be conserved as rigorously and universally as energy. The two particles 'tau' and 'theta' seemed to be identical particles, because they exhibited identical mass and lifetime ; but the parity-conservation law appeared to break down, as inferred from the observation that *tau* decayed into 3 pions and *theta* into 2 pions. Why did two exactly alike particles differ in one respect ? Two alternatives presented themselves to Lee and Yang : *either*, to "save" the "sacred" principle of parity conservation at the same time admitting that two particles having the same mass and lifetime were 'distinct' particles, *or*, to recognize that tau and theta were the same particle but parity was *not conserved* in the case of their decay, i. e. in the case of *weak interactions*. The second alternative, said Yang (Nobel Lecture 1957), "did not appeal to us. Rather we were, so to speak, driven to it through frustration with various other efforts at understanding the theta-tau puzzle that had been made". Experiments confirmed the selective validity of the parity-conservation law for strong and electromagnetic interactions and its violation for weak interactions. Tau and theta could now be thought of as one and the same particle, K-meson.

With the establishment of such selective conservation laws, the theorists renounced the hope of framing a comprehensive unified scheme embracing both the heavier particles or *hadrons* like the pion, K-meson, nucleon, lambda, sigma, xi, etc. (SI-particles) *and* the light particles or *leptons* such as the neutrino, electron and muon (WI-particles). By mid-1950's they became reconciled to grouping the hadrons and leptons under separate schemes governed by different sets of laws. Consistent with the pragmatic generalization that most of the conservation laws governing the hadrons are of little meaning for the leptons, Sakata proposed (1956) his "unified" classification for the multiplicity of hadrons in terms of only three "truly elementary" hadrons : proton, neutron and lambda. This hypothesis was followed up by Ne'emann and Gell-Mann (1961, 1962) who proposed the so-called "Eightfold" classification scheme in terms of an elegant symmetry between Sakata's "elementaries" and two more hadrons, the sigma and xi. Gell-Mann next predicted the existence of the so-called *quarks* and *antiquarks*, i. e. fractional electric charges ($\frac{2}{3}$ and $\frac{1}{3}$ of the electron's or proton's charge) which perhaps might be the "ultimate" constituents of the different hadrons. Ehrenhaft's futile search (1922) for "subelectrons" or particles having fractional electronic charge was a naive anticipation of the recently postulated quarks, which are being searched for in cosmic rays but have not yet been detected.

However impressive may have been the attempts to understand the plethora of particles and antiparticles (82 by 1964) in terms of a small number of truly fundamental particles, "one nevertheless feels", wrote R. D. Hill (1964), "that the basic theoretical understanding of where the many particles fit into our broad comprehension of matter and forces is still awaiting solution". There has been, since 1964, no essential change in that dead-end situation.. We may recall that the introduction of each new particle like neutron, neutrino and meson was greeted with sceptical remarks, but the strong theoretical expectation of their existence and subsequent experimental verification made them acceptable to the dissenting theorists. But the muon and the first "strange" particles were discovered more or less accidentally before physicists had theoretically anticipated their existence and properties. Such particles, said H. Primakoff in 19f4, "no doubt appear 'superfluous' from the point of view of ordinary atomic and nuclear physics only because we lack a deeper understanding of their role". In 1935 the well-known physicist-philosopher Margenau felt disconcerted by the theorists' advocacy of the neutrino hypothesis and commented that "the trend of recent discoveries appears to be away from uniformity and simplicity of explanation"; however, he reassuringly added: "But we may rest assured that the list of discoveries is not yet complete and that, when their ring is closed and an adequate theory connects the facts, uniformity and simplicity will be restored. Antithesis must forever precede synthesis." The new 'superfluous' particles discovered since 1947 are perhaps "closing the ring" and their increasing multiplicity or "antithesis" will perhaps lead to a convincing "synthesis".

In our historical review it is necessary to mention that modern physicists have directed their attention also to the problem of determining the 'inner structure' of the 'elementary' particles which are treated as structureless geometrical points. In the late 1950's Robert Hofstadter experimentally indicated that the proton and neutron (the nucleon, in general) had internal structure, for which he was awarded the Nobel Prize in 1961. Let us conclude our review with what he said in the Nobel Lecture :

> "The history of physics shows that whenever experimental techniques advance to an extent that matter, as then known, can be analyzed by reliable and proved methods into its 'elemental' parts, newer and more powerful studies subsequently show that the 'elementary particles' have a structure themselves. Indeed this structure may be quite complex, so that the elegant idea of elementarity must be abandoned. The proton and neutron, which were once thought to be elementary particles, are now seen to be highly complex bodies. It is almost certain that physicists will subseqently investigate the constituent parts of the proton and neutron...What will happen from that point on ?...My personal conviction is that the search for ever-smaller and ever-more-fundamental particles will go on as long as Man retains the curiosity he has always demonstrated."

Do Quarks Possess Charm and Colour Besides Strangeness?

PARTHA GHOSE
Science Officer, British Council Division,
British High Commission, Calcutta 700016

The ultimate constituents of matter have always excited the inherent inquisitiveness of the human mind. Ancient Indian and Greek philosophers speculated about them. But it was John Dalton who was the first to be able to give modern scientific form to atomic theory. Although Dalton's theory proved instantly useful for chemistry and became the foundation of the kinetic theory of gases and later of statistical mechanics, positivists like Ostwald and Mach launched a severe attack on atomic theory on the ground that scientific theories ought to be formulated only in terms of observable quantities, which atoms were not. It was left to the genius of Einstein to demonstrate for the first time that atoms were indeed real through his masterly interpretation of the Brownian movement.

The search for the fundamental constituents of matter has so far, however, been elusive. Elements have been found to be composed of atoms, atoms of electrons, protons and neutrons (jointly called nucleons), and now we are faced with the question of the structure of nucleons and of the host of other strongly interacting particles and resonances (very short-lived states of matter) which show up momentarily in high energy collisions. Are all of them elementary particles ? That would be hard to believe.

Let us begin by classifying the particles into families according to the type of interactions they manifest. So far as we know today there are four basic interactions in nature :

1. *Gravitational:* this is shared by all bodies having mass.
2. *Electromagnetic:* this acts between electrically charged objects.
3. *Strong:* this is responsible for holding the nuclei of atoms together in tiny volumes of radius approximately $10^{-13} cm$ against violent electrostatic repulsive forces acting between constituent protons.
4. *Weak:* this is responsible for decays such as the β-decay of the neutron, $n \rightarrow p + e^- + \bar{\nu}_e$.

The typical time associated with an interaction is used as a measure of its strength. *Table 1* shows the relative strengths of the four basic interactions. It is clear that the gravitational interaction is so weak as to make it for all practical purposes negligible in fundamental particle interactions even at moderately high energies.

TABLE—1

Interaction	Strength	Typical decay	Time (seconds)
Strong	1	$p \to 2\pi$	10^{-23}
Electromagnetic	1/137	$\pi^0 \to 2\gamma$	10^{-16}
Weak	10^{-13}	$n \to p + e^- + \bar{\nu}_e$	10^{-10}
Gravitation	10^{-40}	—	—

There is a family of particles which have been found to interact only weakly and electromagnetically, They are called '*leptons*'. Particles which interact strongly have been called '*hadrons*'. Hadrons usually also interact weakly and electromagnetically. One striking difference between leptons and hadrons is that hadrons are as a class much more massive. Is that because they interact strongly ? No one knows the answer today. *Tables 2* and *3* list the leptons and some low mass hadrons.

TABLE—2

Leptons	Mass
$e^{\pm}$	0.5
$\mu^{\pm}$	105.7
ν_e	0
ν_μ	0

TABLE—3

Hadrons	Mass in MeV/c^2
n	940
p	938
Σ^+	1189
Σ^-	1197
Σ^0	1192
Λ^0	1115
Ξ^-	1321
Ξ^0	1314
Ω^-	1686
$\pi^{\pm}$	140
π^0	135
η	594
$K^{\pm}$	494
K^0, $\bar{K}^0$	498
$\rho^{\pm}$	778
ρ^0	770
ω	783
ϕ	1020

Leptons are relatively few in number and there is no firm evidence yet that they have any internal structure, but the proliferation of hadrons strongly suggests that these do. It has now become clear mainly through the work of Murray Gell-Mann, that hadrons come in families of 8 or 10 or 1. Hadrons can either be *baryons* which obey Fermi-Dirac statistics or *mesons* which obey Bose-Einstein statistics. The baryons come in octets or deciments and the mesons in singlets or octets. For example $n, p, \Sigma^{\pm}, \Sigma^{0}$, Λ, Ξ^{0}, Ξ^{-} form a baryon octet, whereas $K^{\pm}, K^{0}, \bar{K}^{0}, \pi^{\pm}, \pi^{0}, \eta$ form a meson octet. An example of a meson nonet (singlet plus octet) is furnished by $K^{*\pm}, K^{*0}, \bar{K}^{*0}, \rho^{\pm}, \rho^{0}, \omega$ and Φ.

Quarks

Gell-Mann and Zweig suggested a simple explanation of this orderly structure. They postulated that all hadrons were made up of three fundamental constituents called '*quarks*', a word borrowed by Gell-Mann from James Joyce's 'Finnegan's Wake':

> "Three quarks to Muster Mark".

If we denote these quarks collectively by q and their anti-particles by $\bar{q}$, then according to Gell-Mann and Zweig the observed mesons are $(q\bar{q})$ states whereas the baryons are (qqq) states. In the mathematical language of group theory the quarks and anti-quarks form the fundamental representations of the group $SU(3)$, and representation theory determines, for example, that the nine possible meson states $q\bar{q}$ arrange themselves into a singlet and an octet representation and the twenty-seven possible baryonic states qqq into a singlet, two octets and a deciment: $3\times\bar{3}=1+8$ and $3\times3\times3=1+8+8+10$.

The triplet of quarks q is usually denoted by (u, d, s) for 'up', 'down' and 'strange'. The quantum numbers of these quarks are listed in *Table 4*. Thus, for example, a proton $=(uud)$, a neutron$=(udd)$, $\pi^{+}=(ud)$, $\Sigma^{-}=(dds)$ etc. It is the fractional charge of the quarks which makes them a revolutionary proposition, yet at the same time, one might expect, very easy to observe. However, thorough searches over the last decade have proved futile.

TABLE—4

Quarks	Charge (in units of electron's charge)	Baryon number	Strangeness
u	2/3	1/3	0
d	−1/3	1/3	0
s	—1/3	1/3	—1

If the hadrons are made of quarks, it must be possible to see their structure. The leptons are the 'cleanest' probes for hadrons since they do not have any strong interactions themselves. Very high energy leptons can probe deep inside hadrons and break them up, causing what are known as 'deep inelastic' scatterings. Such experiments have revealed that, for example, the nucleons have pointlike constituents: they appear like raspberry jam with seeds. Feynman has called them *'partons'*, i.e. parts of protons. Are these the quarks ? More and more physicists seem to favour such a conjecture.

Colour

There is a particular process, however, for which the ordinary quark model gives a wrong result. This is the rate of the decay $\pi^0 \to z\gamma$. The quark model predicts a rate three times smaller than the observed one. There are also some problems regarding quark statistics. Quarks are supposed to carry half a unit of spin, and particles which carry half-odd units of spin follow Fermi-Dirac statistics and are called *fermions*. Fermions must obey the *Pauli Exclusion Principle* : no two fermions can occupy the same physical quantum state. Quarks, however, seem to cluster in the same state. The normal statistical behaviour would be restored however, if there existed three triplets of quarks which differed from one another by some yet unknown property that has been picturesquely called 'colour'. There are two different versions. According to Gell-Mann the quarks come in three colours, red, white and blue. To quote again from Finnegan's Wake :

> 'Three jeers for
> grape, vine and brew.
> Three cheers for
> red, white and blue'.

Colour is, however, unobservable according to Gell-Mann. It only acts like a kind of 'charge' (non-electrical !) that attracts quarks strongly to form hadrons, Han and Nambu, on the other hand, also invoke three triplets of quarks with different colours, but their quarks have integral charge and their colour becomes observable at high energies. There can be according to Han and Nambu a 'colour thaw' at the right threshold energy. At low energies however colour is frozen as it were and the two models give identical results.

A simple way to test different quark models would be to measure the ratio of the rates of the two processes $e^+e^- \to$ hadrons and $e^+e^- \to \mu^+\mu^-$. This ratio at very high energies, R_{asy} should equal the sum of the squares of the quark charges. The Gell-Mann model with coloured quarks predicts a value 2 for R_{asy} whereas the Han-Nambu model predicts R_{asy} to be 4.

This ratio is being measured at ever higher energies in different laboratories in the world. Just below 3 GeV centre-of-mass energies R_{asy} was found to approach the value 2 from above. But then something went topsy turvy.

The ψ Story

Between 3 and 5 GeV not only did R_{asy} start rising again but in October 1974 two entirely new particles were unexpectedly discovered in e^+e^- colliding beam experiments, one at 3.1 GeV called ψ and the other at 3.7 GeV called ψ'. These particles were unexpected because they were fairly stable and decayed surprisingly slowly into hadrons in about 10^{-20} sec. To understand the problem, remember that a ρ meson may also be produced in $e^+ e^-$ collisions but it decays into hadrons in 10^{-23} seconds : $e^+ e^- \rightarrow \rho + 2\pi$, But $e^+ e^- \rightarrow \psi \rightarrow$ hadrons take 10^{-20} seconds. Why this difference ? Are the ψ's hadrons at all ? Are they mediators of weak interactions ?

Unification of Weak and Electromagnetic Interactions

To understand the speculations that have been made to interpret the ψ particles, we must go back in time a little and recount the elegant unification of weak and electromagnetic interactions of leptons that was achieved by Abdus Salam and Steven Weinberg in 1968. In classical physics an interaction is described in terms of a field. For example, the electron creates an electromagnetic field around it which acts on another charged body at a distance. Similarly with gravitation. It was in analogy with this concept that in 1932 Yukawa predicted the existence of a field that mediated the strong interaction. In quantum theory, however, fields are also required to possess a corpuscular character. The particles or quanta associated with the electromagnetic field are called '*photons*' and those with the gravitational field '*gravitons*', though the latter have not been discovered so far. The quanta associated with the strong nuclear field are the $\pi^{\pm}$, π^{0}, ρ etc. Now it has been speculated for a long time that weak interactions are also mediated by massive fields and their quanta have been called '*intermediate vector bosons*'.

TABLE—5

Interaction	Mediators
Gravitation	Graviton ?
Electromagnetic	Photon
Strong	π, K, ρ ···
Weak	Intermediate vector bosons ?

Just as the symmetry group of special relativity unifies electricity and magnetism into a single entity, the electromagnetic field, so Salam and Weinberg proposed that the weak and electromagnetic interactions were also unified at a deeper level by the symmetry group $SU(2) \times U(1)$. The difference between the two interactions results only from a spontaneous breakdown of this underlying symmetry. Salam and Weinberg assumed that the electron and its associated neutrino (and similarly the muon and its associated neutrino) were two components of one and the same fundamental entity, a fundamental representation of the group $SU(2) \times U(1)$. Now consider the process

$$e^- + p \rightarrow e^- + p.$$

This is an electromagnetic process. The Salam-Weinberg theory would naturally predict then that

$$\nu_e + n \rightarrow p + e^-$$

would also occur and be a weak process. They also predicted the weak process

$$\nu_e + p \rightarrow \nu_e + p$$

in which there was no change of charge of the proton. A neutral weak current is said to be involved. No firm evidence for such a current existed at the time. But a neutral current has now been discovered in neutrino reactions, giving a big boost to the Salam-Weinberg model. But the neutral current data also implied that the intermediate vector bosons in their model (there are three, $W^{\pm}, Z^0$) must be very, very massive. This ruled out the possibility that the ψ particles were intermediate vector bosons of the Salam-Weinberg type.

Charm

The Salam-Weinberg model when extended to include hadrons ran into a severe difficulty. It predicted the occurrence of the decay $K^0_L \to \mu^+\mu^-$ which involved a strangeness — changing neutral current. But such decays, if they occur at all, are very rare indeed. Fortunately, however, a way out was suggested by Glashow, Illiapoulos and Maiani who proposed that quarks of each colour might not be triplets but rather quartets. In other words they enlarged the hadron symmetry group from $SU(3)$ to $SU(4)$. The fourth quark c of each colour must carry an extra label or quantum number which distinguishes it from the other quarks. This has been called '*charm*'. The charmed quarks cancel the contribution of the ordinary quarks to the process $K^0_L \to \mu^+\mu^-$, thus suppressing it.

It is obvious that this theory would predict a richer hadron spectrum. For example, mesons would be expected to come in singlets and families of 15 : $4\times\bar{4}=1+15$. Of the seven new mesons three should carry one unit of charm, another three a unit of negative charm, and the seventh one should be a $c\bar{c}$ state carrying no charm. Could $\psi(3.1)$ be a $c\bar{c}$ state and ψ' (3.7) its radial excitation ? This is a picture which is finding increasing acceptance among physicists. The stability of the $c\bar{c}$ states is explained by assuming that the charmed quarks have a mass higher than about 1.9 GeV/c^2 so that when they form a $c\bar{c}$ bound state (a '*charmonium*') with mass 3.1 GeV or 3.7 GeV it does not have enough energy to decay into charmed quarks. Moreover its decay into ordinary non-charmed hadrons is hindered by certain quark-model selection rules. The model received a shot in the arm when a couple of intermediate states lying between 3.1 GeV and 3.7 GeV, which were predicted, were actually discovered last year in the USA and West Germany.

If charmed quarks exist R_{asy} should have a value $3\left((2/3)^2+(1/3)^2+(1/3)^2+(2/3)^2\right) = 10/3$. The rise in R between 3 and 5 GeV could be due to the production of charmed states, but it should eventually settle down to its asymptotic value of 10/3.

TABLE—6

Quarks	Charge (in units of electron's charge)	Strangeness	Charm
u	2/3	0	0
d	—1/3	0	0
s	—1/3	—1	0
c	2/3	0	1

News has just reached us (New Scientist, Vol. 70, 20th May 1976 issue) that charm has actually been caught naked at the e^+e^- colliding beam machine SPEAR at Stanford. Sheldon Glashow and his collaborators had predicted, as we have already seen that there should be three spinless states with one unit of charm : $(c\bar{u})$, $(c\bar{d})$ and $(c\bar{s})$. The two non-strange states $(c\bar{u})$ and $(c\bar{d})$ were predicted to have a mass around 1.8 GeV/c^2 and the strange state $(c\bar{s})$ at around 2 GeV/c^2. The $(c\bar{u})$ and $(c\bar{d})$ were predicted to decay predominantly into a $\bar{K}$ and a π while $(c\bar{s})$ was predicted to decay mostly into $\bar{K}K$, $\eta\pi$ and $\bar{p}p$. Although there have been indications for some time from three bubble chamber experiments and two Fermilab counter experiments with neutrinos that charm was no idle speculation of theorists, the statistics were not good enough for an unequivocal judgement. The latest SPEAR data have a far better statistics. They have recorded 60 to 70 unambiguous charm events out of a total of 25000 events, They now claim to have definitely seen a new neutral particle at 1.17 GeV/c^2 which decays into a K^+ and a π^-, This is just as had been predicted. The other charmed particles have also been tentatively identified, one at 2.02 GeV/c^2 and one at 2.15 GeV/c^2. The subnuclear world *is* charming. Francis Bacon once said : "There is no true beauty that hath not measure of strangeness". We can now add : "There is no beautiful truth that hath not a measure of strangeness and charm". What about colour ?

Magnetic Monopoles

This brings us to the topic of magnetic monopoles. An asymmetry between electricity and magnetism that has worried physicists for a long time is that magnetic lines of force are closed whereas electric lines of force are open. To restore the symmetry P.A.M. Dirac conjectured way back in 1931 that magnetic monopoles might exist. It was recently claimed by Buford Price and his group that they had detected a magnetic monopole. Although the experiment attracted a lot of attention, the claim could not be substantiated against less revolutionary interpretations that others have advanced. However theorists have not given up hope. They are now asking the question: are the quarks themselves magnetic monopoles? A strange property of magnetic monopoles is that one can make a fermion out of two bosons (particles with an integral number of units of spin and obeying Bose-Einstein statistics) if one of the bosons is a monopole and the other an ordinary charged particle. In other words, you could add two even numbers and get an odd number. That such a strange thing can happen in some theories (called '*gauge field*' theories) has been recently shown by G. 't Hooft, P. Hasenfratz, R. Jackiw and C. Rebbi (Physical Review Letters, Vol. 36, 10th May 1976 issue). They have shown that the magnetic field of a monopole, interacting with the electric charge of the particle whirling round it could produce a half-odd unit of spin.

The question that arises is : are quarks bosons ? They carry half a unit of spin and normally such particles are fermions and obey Pauli's Exclusion Principle. But as we have already seen in connection with the colour of quarks, quarks behave differently and seem to cluster in the same state, a property typical of bosons. Curiously just such a property is to be expected of combinations of monopoles and charges ! In other words, quarks need not necessarily have colour, they could alternatively be magnetic monopoles, and a pseudo-magnetic field could bind quarks to form hadrons,

Concluding Remarks

The situation still seems to be wide open. Are there quarks ? Are there magnetic monopoles ? If so, why can't we find them ? There have been some interesting suggestions that although quarks exist they are permanently confined within hadrons. They cannot occur singly but always in combinations to produce hadrons. In other words, hadrons behave like 'bags' containing quarks' !

Some have questioned the very existence of any fundamental constituents of matter, their chief protagonist being Geoffrey Chew. They believe all hadrons are composites of one another in a marvellously interwoven system from which you cannot leave out a single hadron without necessarily spoiling its self-consistency. This is called the '*bootstrap*' hypothesis, the reference being to Baron Munchausen who fell into a quagmire and attempted to lift himself up with his own bootstraps. Is this theory equally doomed ? Only the future will tell. At present it is too grandiose a picture to yield to any known scientific and mathematical treatment. It shares with Eastern philosophy the conviction that fundamental truth must be grasped in its totality. It is said that there is a perfect arrangement of pearls in Lord Indra's court in which each pearl reflects all the others. It is a breath-taking conception.

But is the modern quark theory really so fundamentally different from the bootstrap theory ? After all, the quark theory also views all hadrons as composite structures. As Murray Gell-Mann once remarked : "The hadrons are made of quarks. but the quarks ain't there". we cannot help recalling here the late nineteenth century controversy regarding the reality of atoms. Perhaps we have to wait for another Einstein to take us further.

Acknowledgements :

The author is grateful to Mr R. G. Bowers for a critical reading of the manuscript.

Molecular Order in Polymers

SUKUMAR MAITI

Research and Development Centre, Deepak Nitrite Limited, Baroda 391340.

The behaviour of molecules depends on the arrangement of the constituent atoms or groups in the molecule. The atomic arrangement in the molecule, known as molecular configuration, gives rise to different isomers having variation of properties. This phenomenon of dependence of molecular behaviour on its structure is well-known, particularly in organic chemistry. A few examples are illustrated in Fig. 1. However, this fact is even more pronounced in the field of synthetic polymers, commonly known as resins, rubbers and fibres. This is due to the very large size of the molecules of polymers, which consist of many atoms or groups of atoms arranged mostly in a linear fashion. The scope as well as the number of arrangement of these large number of atoms and/or groups is very high compared to simple organic molecules. With the variation of molecular arrangement the properties will also change. The structure-property relationship, therefore, reaches its culmination point in synthetic polymers.

Scope of Varied Molecular Configurations in Polymers

Let us now examine how various molecular structures are possible even in the same polymer. The process of polymer formation, known as polymerization, may be described as the joining of small monomer molecules repeatedly until a long chain-like polymer molecule is produced. Generally an organic molecule with one or more carbon-carbon double bond, acts as the monomer molecule. The double bond of such monomer molecules when activated under the influence of heat, light or energetic chemical species such as free radicals and ions is able to add on to other molecules and constitutes a chain reaction. Monomer molecules may be of two types : symmetric or unsymmetric. When the substituent atoms or groups of both the carbon atoms joined by the double bond are identical, the monomer molecule is said to be symmetric, e.g. ethylene or isobutylene. In unsymmetric monomer molecules the substituent atoms or groups between the two carbon atoms joined by the double bond are not identical, e. g. propylene or vinyl chloride.

When symmetric monomer polymerizes there is little or no scope of variation of molecular configuration in the resultant polymer. But unsymmetric or imperfectly symmetric molecule may add to the other molecule in two distinct modes : 'head-to-tail' or 'head-to-head and tail-to tail' (Fig. 2).

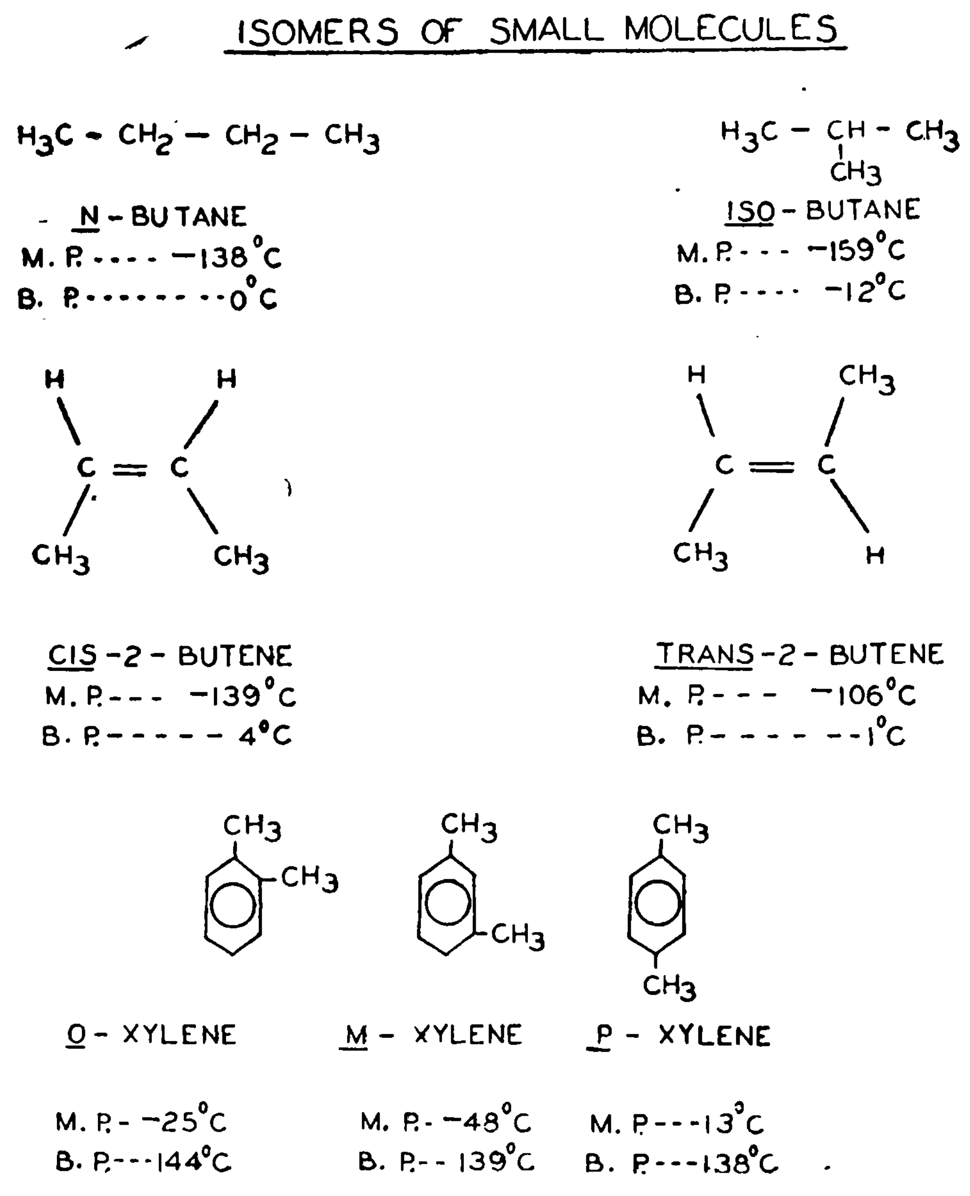

ISOMERS OF SMALL MOLECULES
H3C - CH2 - CH2 - CH3
N-BUTANE
M. P. ---- −138°C
B. P. -------- 0°C
H3C - CH - CH3 / CH3
ISO-BUTANE
M. P. --- −159°C
B. P. ---- −12°C
CIS-2-BUTENE
M. P. --- −139°C
B. P. ----- 4°C
TRANS-2-BUTENE
M. P. --- −106°C
B. P. ---- −1°C
O-XYLENE
M. P. - −25°C
B. P. --- 144°C
M-XYLENE
M. P. - −48°C
B. P. -- 139°C
P-XYLENE
M. P. --- 13°C
B. P. --- 138°C

Fig. 1

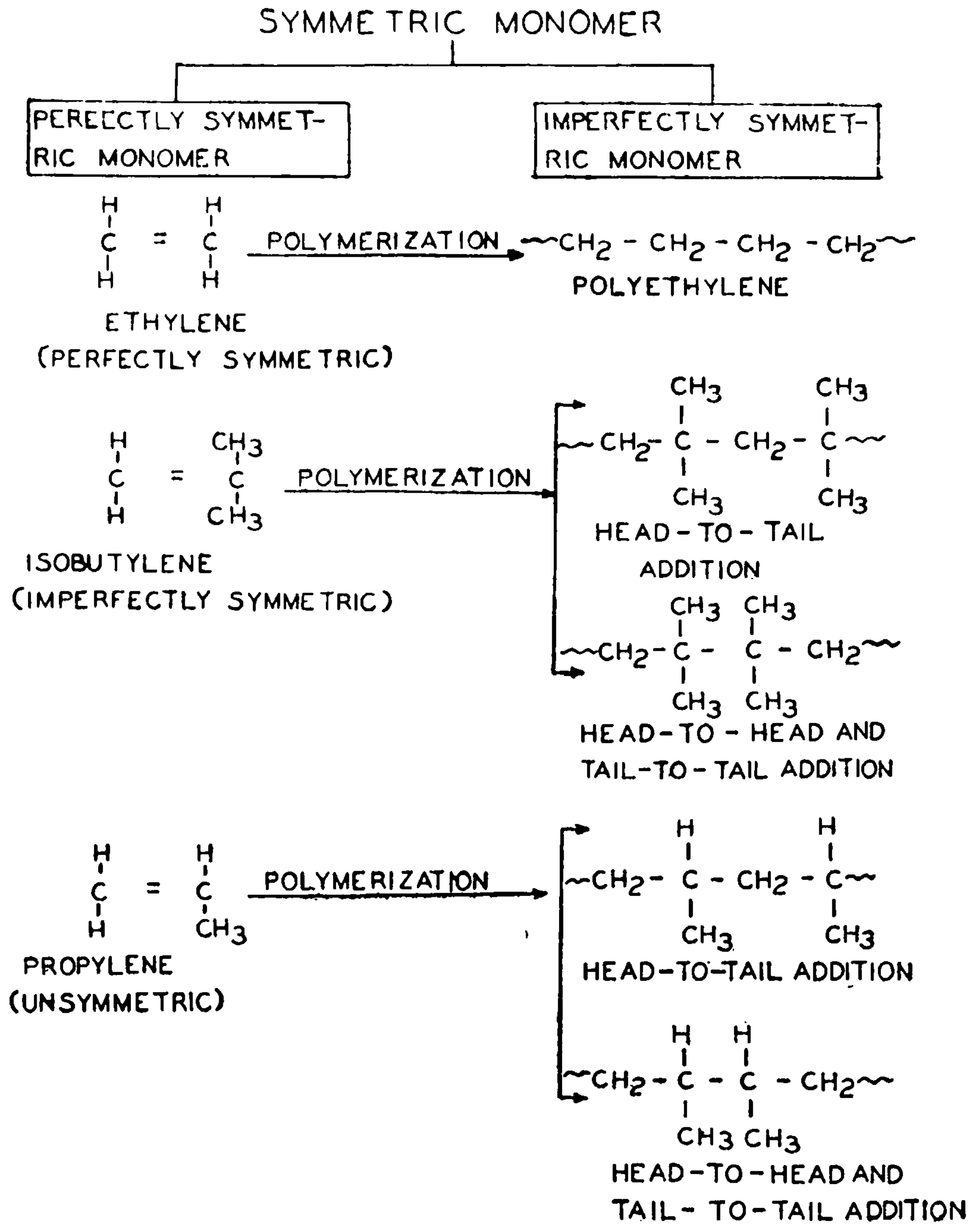

SYMMETRIC MONOMER
PERFECTLY SYMMETRIC MONOMER
IMPERFECTLY SYMMETRIC MONOMER
POLYMERIZATION
~CH2 - CH2 - CH2 - CH2~
POLYETHYLENE
ETHYLENE
(PERFECTLY SYMMETRIC)
ISOBUTYLENE
(IMPERFECTLY SYMMETRIC)
HEAD-TO-TAIL ADDITION
HEAD-TO-HEAD AND TAIL-TO-TAIL ADDITION
PROPYLENE
(UNSYMMETRIC)
HEAD-TO-TAIL ADDITION
HEAD-TO-HEAD AND TAIL-TO-TAIL ADDITION

Fig. 2

Head-to-head or tail-to-tail mode of linking monomer units in a polymer does not usually occur due to accomodation difficulty of bulky groups in the adjacent positions and/or to the polarization of the monomer molecule. Normally head-to-tail linking of monomer units is prevalent in a polymer molecule.

In head-to-tail mode of linking of unsymmetric (not imperfectly symmetric) monomers there is further scope of different arrangement of atoms or groups in the monomer unit. This is possible due to the fact that an unsymmetric centre is made available when an unsymmetric monomer molecule, on polymerization, becomes a monomer unit of the polymer. Now that an asymmetric centre can assume only two modes of spatial arrangement of atoms or groups about it (Fig. 3), the following types of monomeric arrangement may be possible, say, in case of polypropylene (Fig. 4).

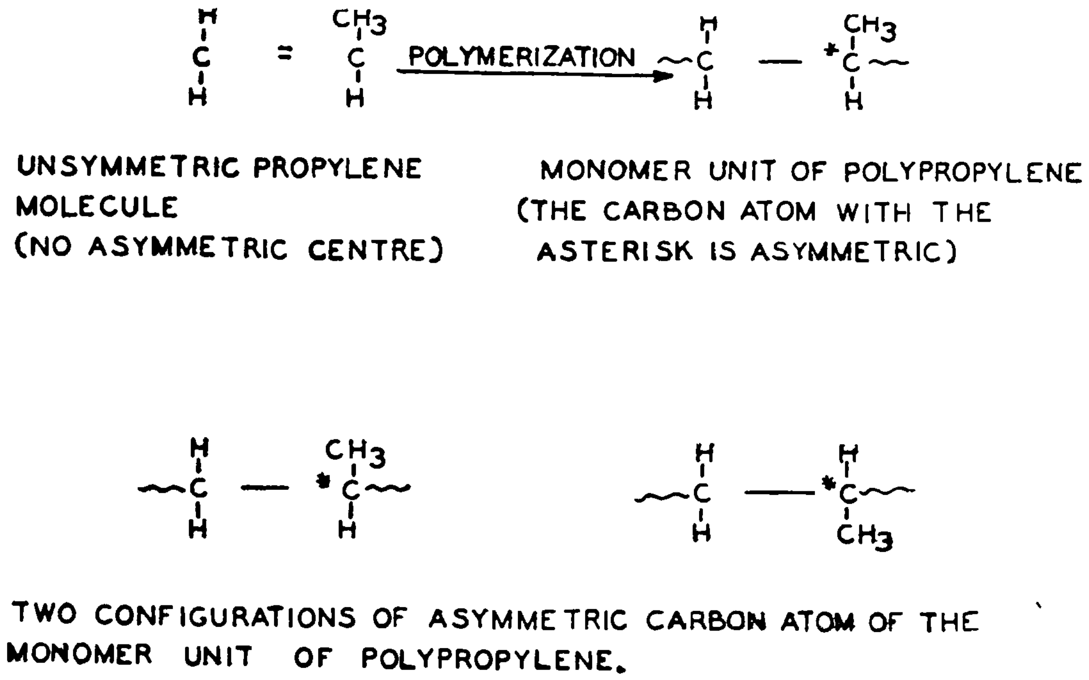


Fig. 3

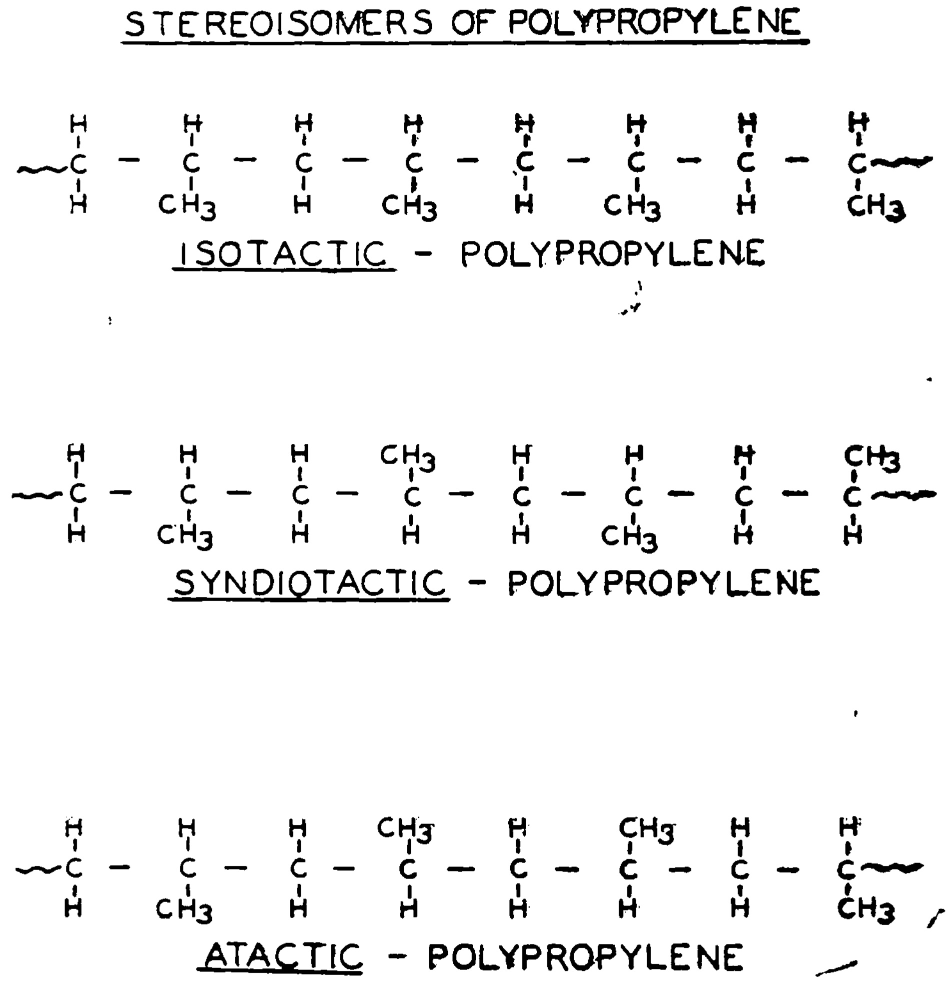


Fig. 4

Although theoretically it is possible to have pure stereoisomers, in practice a mixture of products is obtained. Depending on the process conditions an isotactic polypropylene may contain different amount of atactic or syndiotactic isomers. Even a single chain may contain regions of different stereoisomeric arrangements. These are known as *stereo-block polymers.*

Disorder in Polymer by Copolymerization

One of the subtle ways to bring disorder or to reduce ordered structure in polymers is copolymerization. In copolymerization two different monomer molecules add on to each other and form a large copolymer molecule. The process of copolymerization may be compared to the art of making a chain with different sizes of beads. As a result the chain becomes non-uniform and does not pack closely with other chains (Fig. 5).

HOMOPOLYMER CHAIN

COPOLYMER CHAIN

Fig. 5

There are various types of copolymers. From a comonomer pair, say A and B, four different types of copolymers are possible due to the variation of arrangement of comonomers (Fig. 6).

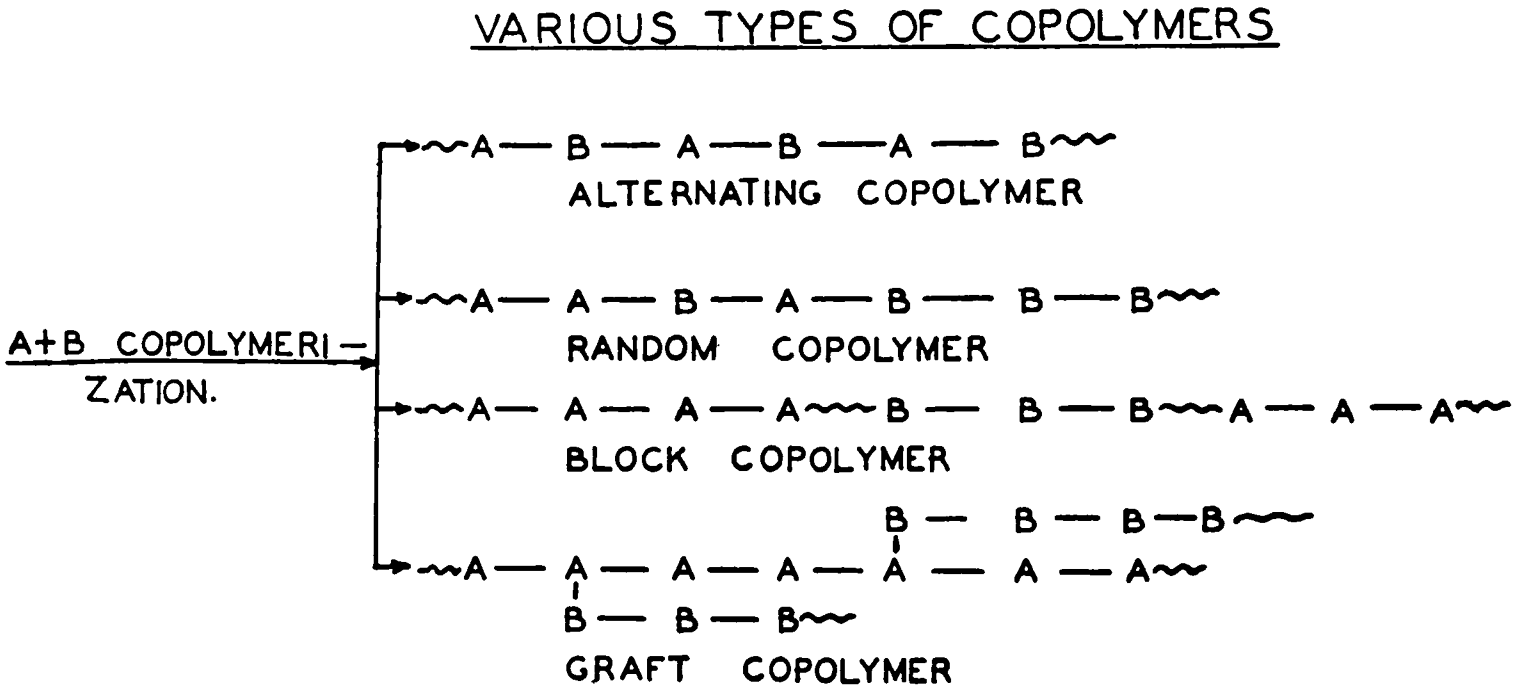


Fig. 6

We wish to point out here that the stereo-block polymer described earlier should not be confused with the block copolymer. The former polymer consists of one and the same monomer unit and is, therefore, a homopolymer. Only the steric configurations of monomer units are different. Block copolymers contain two different monomer units in the chain. The chemical composition as well as molecular structure and size of the monomers are different.

Role of Order-Disorder in Polymers

The unique behaviour of polymeric materials is mainly due to the large size and shape of the molecules. The shape of the molecules is usually controlled by, and during, the process of making the polymer. For instance, the rubber-like properties are usually due to the long chain molecules which are free to rotate about the carbon-carbon bond and therefore assume random coiled structure. To prepare a synthetic rubber every care should, therefore, be taken to prevent the formation of ordered structure in the macromolecule. For synthetic fibres maximum ordered structure in the chain is necessary. Plastics material has got the molecular order between rubbers and fibres.

Polypropylene is a case in point. Isotactic polypropylene is only commercially important for its superior properties than its other isomers. These superior properties of isotactic polypropylene are due to its very high molecular order. Atactic polypropylene with very low molecular order is an undesirable product. The role of order-disorder in polymers has been illustrated in Table 1. By changing molecular order one can import altogether different properties in polymers so much so that the two varieties of the same polymer appear to be totally different materials.

TABLE 1.

Variation of Properties and Behaviour of Polymers with Molecular Structure.

Properties	Ordered Structure of Polymers	Disordered Structure of Polymers
Density	High	Low
Melting Point	High	Low
Solid State Property	Tough and Rigid	Soft and Fexible
Solvent Resistance	High	Poor
Mechanical Performance	Better	Poor
Impact Resistance	Low	High
Crystallinity	High	Low
Gas Permeability	Low	High
Fibre Forming Properties	Excellent	Poor
Heat Stability	High	Low

The Gene As I Understand

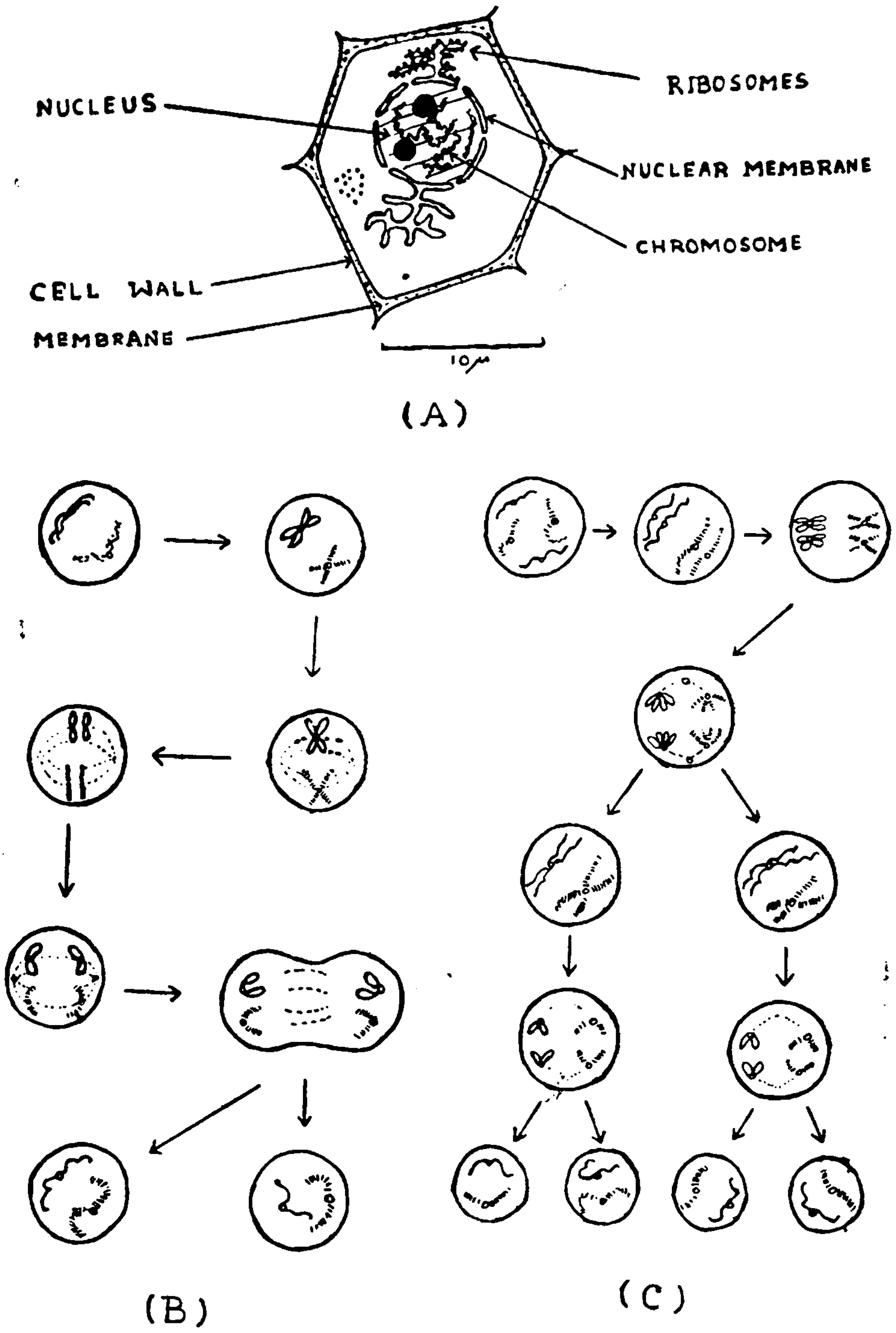
AMAL KUMAR MUKHERJEE
Department of Macromolecules, Indian Association for the Cultivation of Sceince, Calcutta—32.

As soon as man began to use his eyes and brain he realised that "Like begets like"—that humans bear humans and cats have kittens. By nature human beings are curious and people probably wondered about heredity for many centuries. But it was not until the mid-nineteenth century that a valid theory was proposed. Around that time, an Augustinian monk, Gregor Mendel, the "Father of Genetics", working by himself in a small garden in Brunn, was able to accomplish what many others working before him had been unable to do.

In those days he designed, performed and analysed a series of simple, but crucial, breeding experiments with the garden pea, and he succeeded, where his contemporaries failed, because of two major features of his approach: (1) he selected and studied pairs of simple, single-character differences which bred true and (2) he counted as well as classified each individual which resulted from an experimental cross. Thus Mendel's experiments traced the results of breeding experiments between strains of peas differing in well-defined characteristics, like seed shape (round or wrinkled), seed colour (yellow or green), pod shape (inflated or wrinkled), stem length (long or short) etc...He carefully raised these various types of peas for two years before he performed his experiment, to be sure that the offsprings were constantly like the parents and that accidental cross-pollination did not occur. Then Mendel made a number of controlled matings between parents (P) differing in single characteristics such as shape, colour, etc. All the progeny (the first fillial generation (F_1); hybrid is the term used by Mendel) had the appearance of one of the parents. For example, in a cross between peas having yellow seeds and peas having green seeds, all the pregeny had yellow seeds. Similar was the result with all other characteristics tested, that is, progeny resembled one of the parents. The trait that appears in the progeny is called dominant, whereas that not appearing in F_1 is called recessive.

Now Mendel planted these seeds and made genetic cross between these F_1 offsprings. These crosses gave very important results. The recessive trait reappeared in approximately 25 percent of the progeny (F_2) whereas the dominant trait appeared in about 75 percent of them. For all the characteristscs of the plant he studied the ratio of dominant to recessive traits in the second fillial generation (F_2) was approximately 3 : 1. When these experiments were carried to a third progeny (F_3), all the F_2 peas with recessive traits bred true. Those with dominant traits fell into two groups; one-third bred true and the remaining two-third again produced mixed progeny in 3 : 1 ratio of dominant to recessive.

Mendel correctly interpreted his results. But to understand this we should have some knowledge about the cells. In 1839, the German microscopists first established that all plant and animals are constructed from small fundamental units called cells (lower forms of life consist of only one cell also). All cells are surrounded by a membrane. The material inside the cell is known as protoplasm which has a prominent body known as nucleus. Rest of the material of the protoplasm is called cytoplasm. The nucleus is also surrounded by a membrane called nuclear membrane. Each nucleus encloses a fixed number of linear bodies, called chromosomes (Fig. 1-A). Cells arise only from other cells by the process of cell division. This division may occur in two ways. (a) Mitosis is the process in which, before cell division, the chromosome divides to form two chromosomes identical to the parental body. During nuclear division, one of each pair of daughter chromosomes move into each daughter nucleus. As a result of these events, the chromosomal complement of daughter cells is usually identical to that of the parent cells (Fig. 1-B).



(A)

(B)

(C)

Fig. 1

(b) Meiosis is a specialised type of cell division. Unlike mitosis, meiosis produces cells each of which has half the number of chromosomes of the parent cell, with one member of each pair of homologues being represented (Fig. 1-C). Sex cells (gametes) are formed in this way.

Mendel's interpretation was that various traits of peas are controlled by pairs of factors (now called genes), one factor derived from the male parent, the other from the female. Thus pure breeding strains of round peas have two factors (genes) for roundness (say, RR), whereas pure breeding wrinkled strains have two genes for wrinkleness (rr). Each of the round strain gametes has one gene for roundness (R) and the wrinkled strain gametes has one gene for wrinkleness (r). In a cross between round and wrinkled peas, fertilisation produces an F_1 plant with both genes (Rr). The pea would look round because R is dominant over r (see Fig. 2).

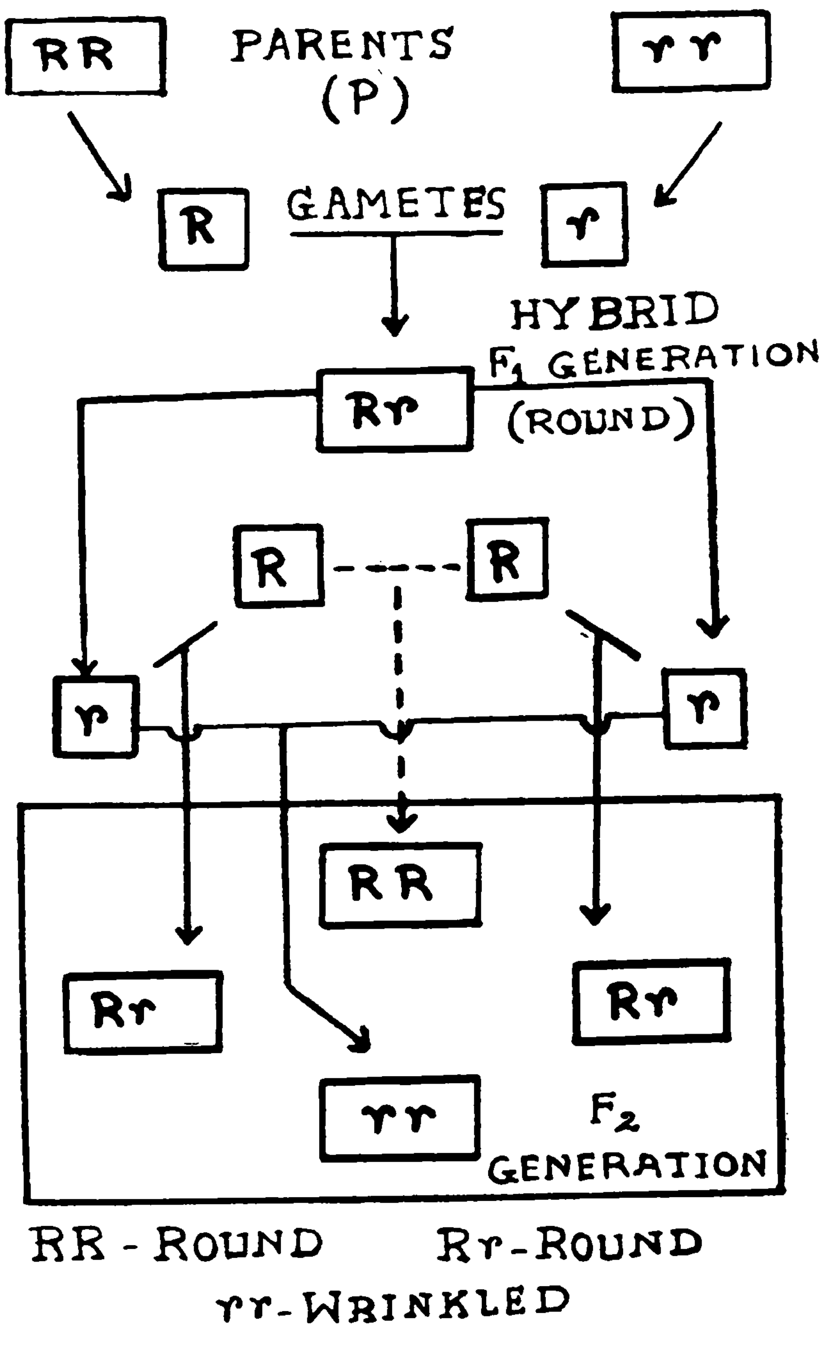


FIG. 2

Now for second generation, two types of gametes are produced in equal numbers. So if a large number of experiments are performed, there will be a 3 : 1 ratio of round to wrinkled peas in the second generation (Fig. 2).

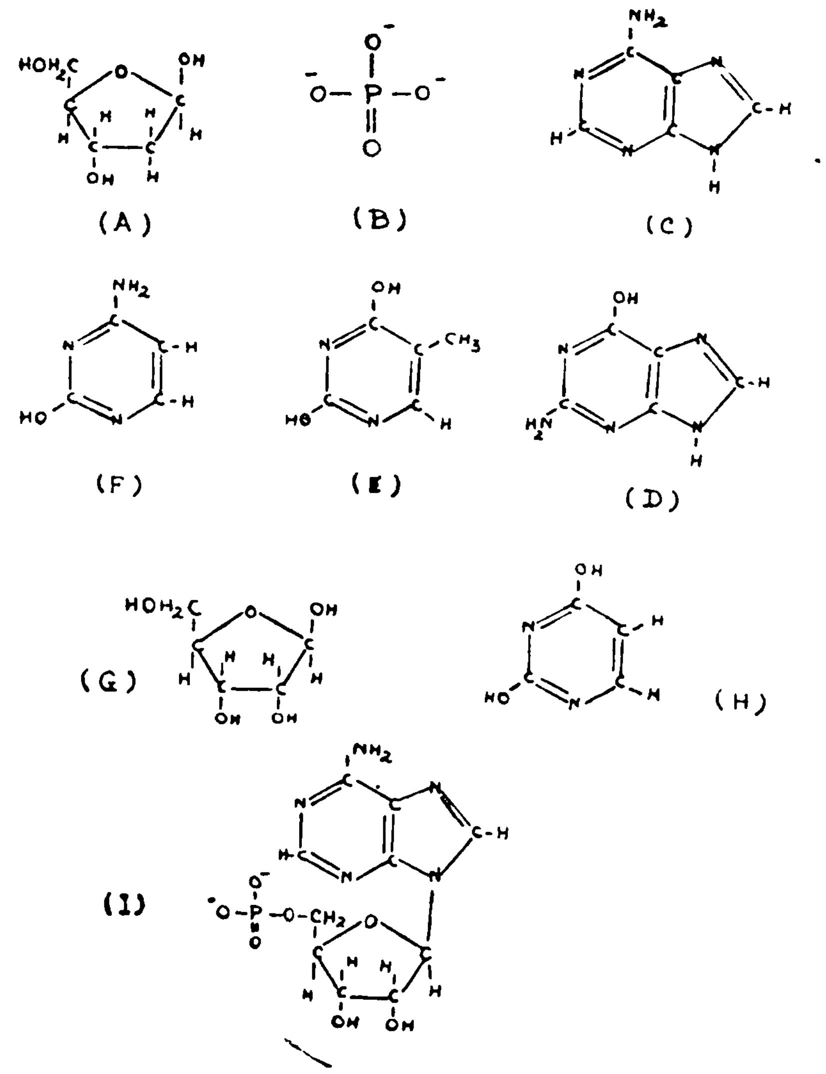
The appearance of recessive character in the F_2 generation indicates that the recessive genes (r) are neither modified nor lost in the hybrid (Rr) generation, but that the dominant and recessive genes are independently transmitted and so are able to segregate, Mendel extended his breeding experiments to peas differing by more than one character also. He published his results of eight years' experiments in 1865. But his ideas were lost for over three decades since the scientific atmosphere at that time was not mature enough to appreciate his discoveries.

The principal reason for the original failure to appreciate Mendel's ideas was the absence of definite knowledge about the behaviour of chromosomes during cell division. Meanwhile nucleic acid was discovered by Miescher in 1869 and knowledge regarding the nuclear location and the behaviour of chromosomes during cell division process were available by the end of 19th century. In 1900 Mendel's laws were rediscovered and were seized upon in 1903 by the American, Sutton. He emphasized the importance of the fact that the diploid chromosomes consist of two morphologically similar sets and that during meiosis, every gamete receives only one chromosome of each pair. He then used this fact to explain Mendel's results by the assumption that genes are parts of chromosomes. Though Sutton's study could not prove the chromosomal theory of heredity, it was very important in the sense that it brought together the independent disciplines of the study of breeding experiment (heredity) and the study of cell structure (cytology). The attention of geneticists was focussed on to find out the chemical structure of the gene and how it acts. No progress could be made since the chemical identity of the genetic material was unknown at that time. Even the realisation that both nucleic acid and protein are present in chromosomes did not really help much since the structure of neither of them was at all understood. The most important speculation that received attention was the one that genes must be self duplicating, that is, their structures must be exactly copied everytime one chromosome becomes two. What then are the genes, where are they located and how do they function ?

Most of the answers to these questions have been obtained from experiments with microorganisms and there is no reson to beleive that the structures and functions of the genes of microorganisms differ from those of multicellular organisms. Until the forties of this century the number of chemists working on nucleic acids (the genetic material) was but a tiny frction of the number attempting to understand proteins. It was known that two nucleic acids, DNA (deoxyribonucleic acid) and RNA (ribonucleic acid) exist and that DNA was found only in nuclei (hence the name) of cells, but the general features of theirc hemical structures had not been elucidated.

The real proof of the genetic role of DNA came in 1944 from the researches of Avery and his associates Mac Leod and Mc Carty at the Rockefeller Institute in New York. They made the momentous discovery that the hereditary properties of pneumococcii can be specifically altered by addition of carefully prepared DNA of high molecular weight. Their work provided much impetus for a detailed chemical investigation of nucleic acids.

Basically DNA has three component parts: deoxyribose (Fig. 3—A) (a sugar), a phosphate group (3—B) and four nitrogeneous bases viz., adenine (A) (3—C), guanine (G) (3—D) and thymine (T) (3—E) and cytosine (C) (3—F). RNA also has three similar component parts, a sugar component, ribose (3—G), a phosphate group, and the bases, adenine, guanine, uracil (3—H) and cytosine. The group of bases adenine and guanine are known as purine bases and the others, thymine, cytosine, and uracil are pyrimidine bases. A unit formed by the union of the components—a sugar, a phosphate and a base in a particular fashion (3—I) is called nucleotide. DNA is a very large molecule formed by polymerisation of the different nucleotide units (may contain a few thousands of such units).



FIC 3

Chargaff and his associates in New York analysed the nucleotide components of DNA from a number of different organisms. From their researches it became clear that (1) the exact ratio of four nucletoides varies from one species to another and (2) that in a particular DNA sample, the amount of adenine is always equal to that of thymine and the amount of guanine is equal to that of cytosine. These studies helped very much in settling the 3—dimensional structure of DNA.

It was through the studies of Todd, Brown and many other that the general polymeric structures of nucleic acids were established. Polymerisation occurs by union between sugar and phosphate groups in a particular fashion and the bases are attached to the sugars at a particular point (Fig. 4—A). Finally, from the X-ray diffraction studies of Wilkins and his associates of King's College, London, and Watson and Crick of Cavendish Laboratory, Cambridge, the double helix

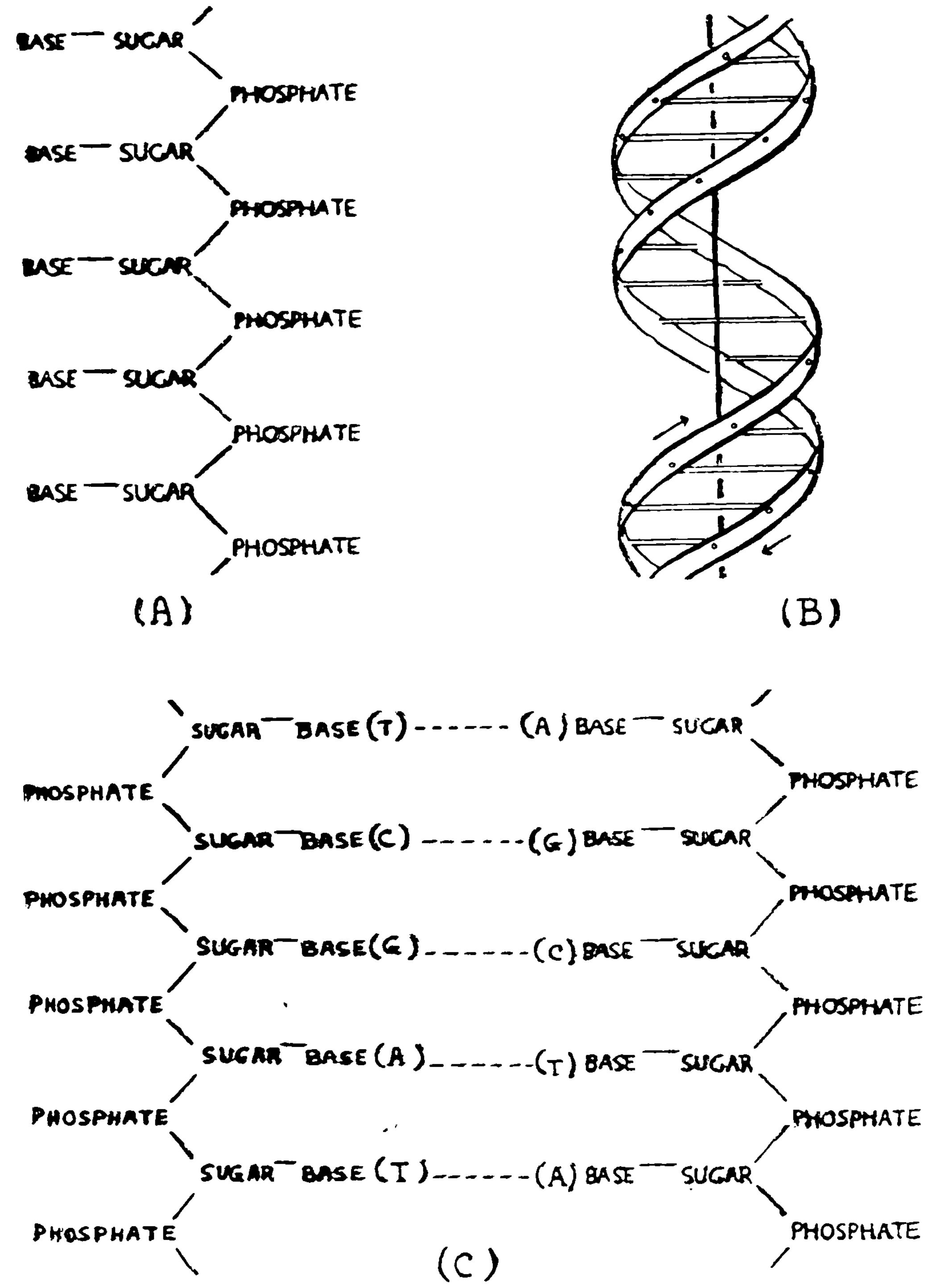


FIG 4

structure of DNA (known ast he Watson-Crick model) evolved (Fig. 4—B). The first biologically important feature is that, in this structure there are two long DNA chains which are coiled around a fibre axis. The second biologically important feature is the manner in which the two chains are held together. This is done by hydrogen bonds (weak) between the bases. The third point is that the bases are joined in pairs ; a single base from one chain being hydrogen-bonded to a single base from the other chain shown schematically in figure (4—C). The important point is that only certain pairs of bases will fit into the structure.

Adenine fits only with thymine and guanine with cytosine. This pairing strongly supports the analytical results of Chargaff and his co-workers.

DNA is located in the nucleus, particularly in the chromosomes of the nucleus of the cell. During cell division the chromosomes replicate into two identical halves and finally form the new cells. The Watson-Crick model of the DNA molecule can explain how the genetic material can duplicate exactly into two. It is hypothesised that prior to duplication the hydrogen bonds are broken, and the two chains unwind and separate. At the some time, each chain acts as a template for the formation of a new companion chain on itself, so that eventually we have two pairs of chains where we had only one before. Moreover, the sequence of pairs of bases will have to be duplicated exactly.

To understand the gene action for the cell one has to know some other components of the cells. The chemical reactions of a living organism are under the control of enzymes produced by the cells. Enzymes are nothing but specialied proteins acting as catalysts to increase the rate of such chemical reactions, and allowing these to occur in the environment of cells. It is supposed that a long DNA molecule is composed of many genes being separated by some inactive parts. One such gene can make one enzyme. These proteins have amino acids as the building blocks. It is the sequence of amino acids in lhe protein molecule that gives the specific property to it. We shall see later that the sequence of the amino acids in the protein is governed by the nucleotide sequence of the gene. There are three kinds of RNA in a cell : (a) sRNA (soluble RNA or transfer RNA or tRNA) small sized RNA. capable of linking up specific amino acids and transfering them to the protein synthesis machinery. There is one specific sRNA for each amino acid. (b) rRNA (ribosomal RNA), large molecules present in the ribosomes which are protein synthesising factories in cells. (c) mRNA (messenger RNA) are formed on the DNA surface and shifted to synthesise protein on the ribosomal surface.

To synthesise a specific protein, DNA first synthesises RNA with the help of an enzyme similar to the mode self duplication, except that deoxyribose is replaced by ribose and thymine by uracil. The base sequence of this mRNA is thus similar to that of the gene on which it is formed. This process is known as transcription, and the mRNA is said to carry the message from the gene. The mRNA is released to the cytoplasm and is deposited on a group of ribosomes (polysomes). Governed by the nucleotide sequence of the mRNA, the sRNAs carry specific amino acids and deposit them one by one on the ribosomal complex (these however need some energy source). There the amino acids are attached to one another in the correct sequence and a protein is formed. The process is called translation. A group of three nucleotides in a particular sequence of the gene codes a particular amino acid of the protein. Ochoa, Nirenberg, Khorana and many others workeda lot on codes (language of the gene). Different genes make different enzymes to carry out functions of the cells. Since the genes are duplicated when an organism goes to the next generation, it is expected that the character of the offsprings will be similar to that of their parents.

It is however not possible that their will be no mistakes. Sometimes some uncommon bases, or even the same base in an uncommon form may spontaneously appear in the structure and thus cause mutation. Very little is known about the molecular basis of the control of protein synthesis in multicellular higher organisms and it is very difficult to attack the molecular basis of normal differentiation. It is therefore very difficult to understand failures in cell heredity which produces abnormal cells unable to integrate into organised multicellular complexes (disease' cancer). Our chance to understand a disease depends greatly upon whether it is based upon abnormalities in molecules with which we are already familiar.

Air Pollution

SAKTIPROSAD GHOSH
Department of Inorganic Chemistry, Indian Association for the Cultivation of Science, Calcutta—32.

"Which is more useful, the Sun or the Moon ?" asks Kuzma Putkov, the Russian philosopher (a character of fiction created by the Russian poets Alexei Tolstoy and brothers Gemchushinkov). After some reflection he answers himself: "The Moon is more useful, since it gives us its light during the night, when it is dark ; whereas the Sun shines only in the day time when it is light anyway". —A man of science is apt to consider this a ridiculous statement made by one of the type comic characters of fiction ; but on a second thought most of us will be forced to admit that the idea of the common man about the role of the sun in the creation and maintenance of life on this earth is not of a much higher standard than that of the philosopher of fiction. Such is also the case with our idea and consciousness about our environment in general and the atmospheric air in particular. So far as the common man is concerned, his ignorance of the absolute necessity of air for the existence of his life, his lack of consciousness about the requisite purity of the air he breathes for his safe living and maintenance of good health is colossal ! His lack of consciousness about the rapid rate at which the atmospheric air is being polluted during the last few decades and the resultant impending danger to human life is again colossal ! It is high time that the common man is made to realise this hazard which threatens the human life as a whole.

A quarter of a century ago, even the environmental experts did not recognize this global hazard to the human race. But air pollution has been long around. The natural causes of air pollution were volcanic eruptions, storms, putrefication of animal and vegetable matters, forest fires etc. The first serious pollution of air by man began with the burning of wood and coal which produced soot, fumes of sulphur dioxide, carbon monoxide, carbon dioxide and many organic compounds. The industrial revolution introduced large scale air pollution, specially in the Western countries. As time marched on, industries expanded at a tremendous rate and polluants other than coal products became increasingly hazardous to man's health.

Air polluants are substances which, in sufficient concentrations, produce a measurable harmful effect on man, other animals and vegetations. Primary polluants are those which are emitted from identifiable sources, e. g., soot, carbon dioxide, sulphur dioxide etc. from coal burning. Secondary polluants are produced by the interaction of two or more primary polluants with themselves or with other atmospheric constituents. Over one hundred different air polluants have been identified so far and among them are included organic and inorganic compounds, metallic and non metallic elements.

Three processes are mostly responsible for the emission of polluants on large scale. These are burning, vaporizing and dividing of materials. Among the processes grouped under burning are coal and other fuel burning, heating to decomposition, roasting, smelting, coking ete. and the major polluants generated are soot, sulphur dioxide, carbon dioxide, carbon monoxide, oxides of nitrogen and some volatile organic compounds. Vaporization process includes distillation, evaporation, petroleum refining, coal tar distillation etc. Benzene and related compounds, benzene soluble coal tar derivatives etc. are among the polluants generated. Crushing, grinding and sieving come under the process of dividing of materials and contribute dust particles and small particles of ores, minerals etc. to air pollution.

When all or most of the polluants accumulate to a large extent in an almost static atmosphere the result is the horrible phenomenon *smog*—a hybrid of smoke and fog—an exclusive product of modern industrial civilization. The atmosphere of a modern city closely resembles the reaction chamber of a large chemical manufacturing unit in which the various primary polluants interact and produce a large number of secondary polluants and admixtures of the primary and the secondary polluants. Sun's rays supply the necessary energy and cause the various industrial, vehicular and domestic emissions to interact photochemically with water vapour and with one another producing smog and ozone. In a windless day, a lighter layer of warm air rests over another denser layer of cooler air just like a lid on a pot. The air polluants collect inside this bi-layer assembly and gradually increase in concentration as it cannot be dispersed away either vertically or horizontally due to lack of air current. This gradually thickening mass of polluants enclosed between two layers of air differing in density and temperature is called smog. Smog can cause burning eyes, irritation of mucous membranes, respiratory and cardio-vascular disease and even cancer and death. The name smog was given in 1911 by Dr. Harold Antoine Des Voeux in his report, "The Glasgow Episode", on an air pollution disaster in London which took the life of more than a thousand people. In the year 1948, in Donora of the Pennsylvania State, U. S. A., the industries producing steel, wire, sulfuric acid, zinc metal and various pharmaceutical products released enough polluants into the air that resulted in a horrible smog that totally enveloped the area. Forty three percent of the population became ill. Nearly a hundred people died and over six thousand became sick and bed-ridden with chest constriction, headache, vomiting, and irritation of eyes, nose and throat.

The specific effects of air pollution on human beings have been studied by clinical experts and it has been found that several different polluants produce similar effects. It has been noted that the principal effect of sulphur dioxide, formaldehyde, acrolein, ozone and chlorine is irritation. Of these chlorine, in large doses, causes permanent damage to the respiratory system. Most of the common air-suspended polluants including dust and soot cause blockade of the respiratory passage. Carbon monoxide can cause many symptoms like headache, visual difficulty, ataxia, paralysis, coma and death. Lead mostly affects the nervous system. The normal development and maturation of the red blood cells is hampered by lead. Both lead and carbon monoxide come from burnt fuel and tobacco smoke. Gasoline contains the antiknock compound tetraethyl lead and the tobacco acquires lead from lead insecticides used when the tobacco is grown in the fields. A tobacco smoker thus accumulates lead poison. Carbon monoxide has a tremendous affinity for haemoglobin of blood and reacts with it two hundred and ten times faster than oxygen, producing carboxy haemoglobin and hampers normal purification of blood by oxygen to an enormous extent. Thus lead and carbon monoxide attack respiration in two different manners. Some of the symptoms of carbon monoxide poisoning begin to appear when the carbon monoxide content of air exceeds hundred parts per million parts. It has been noted that in heavy traffic conditions, carbon monoxide concentration in the atomosphere of the big cities of U. S. A. and Europe sometimes becomes as high as five hundred parts per million parts. A cigarette smoker may have 4-8% of his haemoglobin as carboxy haemoglobin and when we take into account the carbon monoxide from automobile source along with this, the danger of carbon monoxide poisoning reaches alarming proportions in a crowded modern city ! Other dangerous polluants emitted with tabacco smoke are oxides of nitrogen, tarry materials containing α-benzopyrene, which, mixed with dust or soot have been found to initiate lung cancer in rats, guineapigs and rabbits.

Ozone is produced as a result of smog formation and photochemical reactions between some primary polluants and water. It has been noted that exposure to even one ppm of ozone for eight hours a day leads to the development of symptoms of bronchitis, fibrosis and broncholitis.

The presence of more than 2—4 ppm of sulphur dioxide is positively harmful. It changes the cilliary action accompanied by proliferation of the mucous glands. The principal effect of sulphur dioxide is the inability to move air in and out of the lungs. Sulphur dioxide is also changed to sulphuric acid by its interaction with ozone and water vapour. The physiological effect of sulphuric acid is similar but more rigorous than that of sulphur dioxide.

Dust particles suspended .n air are a big and dangerous source of pollution. In a big modern city there are one hundred thousand to one million dust particles in every cubic foot of air. With every breath a man inhales about ten thousand to hundred thousand dust particles. A city dweller inhales about one and a half pound of dust every year. Soot particles over five microns in diameter are caught in the mucous membrane inside the nose and throat but the smaller particles reach deeper portions of lungs. Though soot itself is harmless, the chemicals adsorbed on the soot may cause many disorders.

In these days of experimentation with nuclear devices the atmosphere contains small but significant amount of radioactive materials. These are carried by air currents, dust particles and clouds to distant places far away from the site of nuclear explosions. The size and nature of the particles carrying the activity determine its destination within the body. One of the many radioative isotopes produced by nuclear explosion, Strontium ninety (Sr^{90}), is extremeley dangerous to man, especially to the people of the eastern world who suffer from chronic malnutrition. As it resembles Calcium in most of its properties, it is easily taken up by the plants from which it is transmitted to human beings through food of vegetable origin and also through animal products as the animals feed themselves on the affected vegetation. This Strontium ninety gradually accumulates in the bone and continues to emit extremely harmful β-radiation.

Who is to blame for the present air pollution hazard ? This question naturally presents itself. There can be no doubt that Industry is a very big contributor but the recent findings indicate that greater part of lung level pollution originates from domestic sources. Sewage treatment, garbage and leaf-burning, cooking and home-heating and automobile pollution are the most important domestic sources of pollution. Among these the main culprit is the automobile pollution. Of the 600 tons of nitrogen oxides entering the City of Los Angels, U. S. A. every week, nearly 400 tons come from automobile exhaust gas. Apart from nitrogen oxides, large amounts of carbon dioxide, carbon monoxide, sulphur dioxide, airborne lead compounds and admixtures of various hydrocarbons and soot are set free by the automobiles.

Industrial sources of pollution include refineries, pulp and paper mills, jute mills, cement factories, smelters, fertilizer plants, chemical and pharmaceutical works etc. Transportaion industries such as trucking, railways and airlines are sources of large scale air pollution. While taking off, a commercial jet airline remits polluants at a rate equivalent to that of 10,000 passenger cars. An average sized metallurgical plant alone puts about 50 tons of sulphur dioxide in a single day. A ton of fuel oil used for industrial heating, produces 600 lbs of sulphur dioxide, 27 lbs of nitrogen oxides and 5 lbs of solids. 40 lbs of sulphur dioxide and 8 lbs of nitrogen oxides are produced from the burning of 1 ton of coal.

In a modern city an average home collects 2-3 lbs of dust per week. Almost unbelievable amounts of dust-falls were recorded sometimes. In one month dust-fall in the Chicago City once amounted to 125 tons per square mile and in Wheeling in West Virginia (U. S. A) 590 tons af dust fell on a single squre mile in about a month.

All the above pollution data are startling but when we consider pollution by industries along with domestic pollution the graveness of the impending pollution hazard assumes alarming proportions. But the common man is very little aware of this danger. To make the common man realise the importance of keeping the air pure and clean, it may be pointed out that the average man requires about 14.5 kgs of air but only 1.25 kgs of food and 2.25 kgs of water per day. A man can live 35—40 days without food, 5—7 days without water but only about 5 minutes without air. The senses of sight, smell and hearing are also dependent on air and air pollution affects the senses of sight and smell tremendously. The popular belief that we are at the bottom of an endless sea of air is entirely wrong. If we focus our attention on a students' globe containing the map of the world. the layer of varnish on the globe's surface is indeed very thin. The habitable portion of the atmosphere surrounding us is about as thick as this coat of paint on the desk globe's surface.

In regard to air pollution the relationship between ecological changes and increase in carbon dioxide content of the atmosphere is extremely important. The amount of fuels burnt is increasing resulting in the release of more and more carbon dioxide into the air. Side by side with this, huge areas of carbon dioxide absorbing vegetation are being destroyed to provide space for new roads, factories and cities. As a result of this, increase in carbondioxide content of the atmosphere is of the magnitude of 6 million tons per yer. This enormous and steady increase of carbon dioxide is capable of raising the atmospheric temperature by 40°F within 500 years by the trapping of heat radiated by the earth. This is what is known as the 'green house effect'. A change of tempeature of even 20°F would cause fearful storms that would lead to utter destruction. The polar caps would melt and large coastal areas would be completely inundated causing great floods like those mentoned in the Bible.

The effect of air pollution on health is of more imminent concern to us at presnt. The most dangerous consequence of air pollution, especially of the smog, is that it does not generally initiate fatal respiratory or cardiovascular attacks. On the contrary, it generally acts in a subtle manner by slowly and steadily increasing the respiratory and cardiac troubles which inches a person towards death. Only acutely sick person are pushed to their ends. The premature baby, the newborn, the old, the diseased, those with cardiovascular troubles and those suffering from chronic malnutrition are the most susceptible. The symptoms of air pollution victims range from ill-defined discomfort, illness and chronic disease to acute pain and sickness and even death. The mucous membrane may be affected by specific toxic reactions, by allergenic activity or even by carcinogenic activity. At present it seems that air pollution is a more imminent danger to the human race than the nuclear weapons about which we worry so much and all the time.

Industrially advanced countries like U. S. A., Canada, Russia, European countries, Japan and China and even our own country have now become aware of this impending danger. Some of these countries have given prime importance to the study of environmental pollution and are searching for effective ways of preventing pollution. International bodies have also been formed whose tasks are to make worldwide survey of environmental pollution and suggest remedies. But still the extent of endeavour put forward to tackle this great problem is far from being sufficient. An all out attempt to deal effectively with the problem of air pollution must be made before it reaches the limit of human control. If the human race intends to survive and thrive it has to act now on a war footing with all the resources at its disposal. Otherwise it will face utter destruction, a horrible end, unprecedented in the history of the human race.

Zinc in Crop Production

AMAR NATH PAUL,
College of Agriculture, University of Calcutta,
35, Ballygunge Circular Road, Calcutta-19

The green plant, like all organisms, requires three major classes of nutrients :
(a) Oxidisable organic food stuffs,
(b) Mineral elements and
(c) Water.

The green plant differs from most organisms in being autotrophic in its organic nutrition ; that is, it has the ability to reduce atmospheric CO_2 to the level of sugar by means of radiant energy and the photosynthetic apparatus of the chloroplast and is thus independent of any external supply of oxidisable fuel.

In addition to the organic materials produced in photosynthesis, the plants require a wide variety of mineral elements. These minerals, absorbed from the soil by the root system and transported upward in both xylem and phloem, are required for structural purposes in the cell and for the formation of specific catalytic molecules called enzymes, which regulate the metabolism of all cells. All the elements, except one i. e., nitrogen, are ultimately derived from the parent rock giving rise to the soil ; nitrogen is ultimately derived from the atmosphere, mainly through the process of nitrogen fixation.

Ten essential elements e. g., C, H, O, P, S, K, N, Ca, Fe, and Mg, are required by each plant to complete its life cycle. In addition to these ten, there are other elements, which are required in very small amounts for normal and disease free life of plant. They are Cu, B, Cl, Mo, Zn, Mn and Si and are called micronutrients. The specific role of each of these micronutrients in plant growth proccsses is not well understood. Available information suggests that some of them are effective through certain enzyme systems. For example, Zn and Mn function in enzyme systems which are necessary for important reactions in the plant system. Zn is also thought to be connected with the formation of some growth hormones and reproductive process of certain plants.

Availability of zinc in soils is determined by (1) Soil pH, (2) nature and content of soil organic matter, (3) parent material of soil and (4) agronomic and fertilizer practices. Use of heavy phosphatic fertilisation are known to render zinc unavailable.

Distribution of Zinc in Indian Soils

Many Indian soils are reported to be deficient in zinc and yields of crops grown on those soils have been increased by zinc application.

Alkaline soils are likely to be deficient in zinc. Available zinc of soils are reported to vary from 4.3 to 6.3 ppm in fertile alluvium, 7 ppm in virgin red soil, 1.1 to 3.8 ppm in black soil and 1.2 ppm in laterites.

Role of Zinc in Plant Nutrition

The optimal requirement of Zn in sand culture for barley has been shown to be 1.72 ppm as against 2.53 for rice, 1.97 for maize and 1.31 for sugarcane. The efficiency of different plants to use zinc in dry matter production rises as rice→maize→barley→ sugarcane. Uptake of zinc increases crude protein content of plants. A major proportion of zinc is required by rice at the milk stage.

Most of the Indian soils contain sufficient amount of zinc, yet plants growing on some of them have occasionally been found to exhibit the deficiency symptons. So the availability of zinc to plants is an important factor. It has been found in pure clay minerals that the whole of the Zn present in the clay lattice is not exchanged for other cations. So a portion of Zn is unavailable i. e., fixed. The extractable Zn is much greater in the soils having illite and/or kaolinite as predominant clay minerals than in the case of those which are predominant in montmorillonite [1]. The high dosages of phosphorus in the nutrient media have been reported to accentuate zinc deficiency and lead to reduced growth and to a reduced yield potential of crops.[2,3,]

The site of phosphorus-zinc interaction has been recognised in the root zone[4,5,6] and the zinc deficiency has been attributed to the immobilisation of zinc owing to the increase in the concentrations of phosphorus in the roots, above the normal dose of P supply i. e., 30 ppm of P.[7,8].

But Edwards and Kamprath[9] showed that 'P' treatments did not affect *Zn*-translocation to the roots. More Zn accumulated in the roots at low temperatures than at higher temparatures. Total Zn-accumulation was reduced markedly as light intensity was decreased. Low light intensity reduced root growth more than shoot growth.

Zinc deficiency is common in plants growing on calcareous soils, although the zinc content of these soils is no less than that of non-calcareous soils, which supply adequate zinc to plants. Zinc adsorption by carbonates on precipitation of zinc hydroxide or carbonate may be partly responsible for the zinc unavailability in calcareous soils[10].

Studies related to the unavailability of zinc to plants, such as fixation of zinc by clay minerals, adsorption of zinc by calcareous soils, phosphorus-zinc interaction etc., have been undertaken by various workers but the exact causes for which zinc becomes unavailable to the plant are still unknown.

Zinc Application and Crop Responses

Response to zinc appears to be universal both in horticultural and agricultural crops.

Orange trees suffering from mottle leaf and gradual deterioration have benefited by Zn-application. It has also been found that a level of 2.0 ppm Zn increaed yield and vitamin C content of tomatoes, further dose depressing both yield and quality.

Pereira et. al.[11] showed that application of $ZnSo_4$ to a red latosal significantly increased yields of maize.

Shukla and Prasad[12] found that increase in yield by the application of both ZnO and $ZnSo_4$ in wheat is almost double.

Use and Scope of Radio-Isotopes of Zinc in Agricultnre

In recent years a great many investigations employing radioactive isotopes have been made to study the relationship between solutions and the exchange materials, snch as, soils, clays and resins.

It is possible that well planned experiments using radio-active ^{65}Zn will give the information necessary to explain some of the still unsolved mysteries of zinc in the growth of plants mentioned above.

References :

(1) R. K. Chatterjee, 10th International Congress of Soil Science, 11 1974.
(2) A. L. Brown *et al*, Soil Sci. **110**, 415-20, 1970.
(3) D. W. Thorne, Agron. J. **60**, 453-56, 1968.
(4) J. F. Loneragan and C. J. Asher, Soil Sci. **103**, 311-318, 1967.
(5) K. C. Sharma *et al*, Agron. J. **60**, 329-32 1968.
(6) K. C. Sharma. *et al*, Agron. J. **60**. 453-56, 1968.
(7) R. S. Dwivedi *et al*, Plant and Soil, **43**, 3 639-648, 1975.
(8) L. C. Brown *et al*, Soil Sci. Soc. Amer. Proc, **28**, 229-32, 1964.
(9) J. H. Edwards, and Kamprath. E. J. Agron. J. **66** (4) 479-482, 1974.
(10) E. J. Udo, *et al*, Soil Sci. Sco. Amer. Proc, **34**. 405-407, 1970.
(11) J. Perira. *et al*, Agronomia, **8** (7), 187-199, 1973.
(12) U. C. Shukla, and K. G. Prasad, Agron. J. **66** (6), 804-806, 1974.

Computer : A Brief Perspective

SAMIR SAHA
Department of General Physics & X-rays
Indian Association for the Cultivation of Science, Calcutta-32

One of the most precious gifts of science and technology to the twentieth century is the computer. A computer is a very sophisticated machine that can perform hundreds of thousand operations in less than a second without the need of any manual intervention. Computers are of two basic types—*analog* and *digital.* The analog computer uses continuous internal variable such as electric voltage or current to represent quantitatively the variables of the computation. The digital computer, on the other hand, uses discrete voltages as numeric symbols '0' and '1'. The digital computers are far more versatile and all modern computers are of digital type.

A computer is constituted of a *central processing unit, memory* and *peripherals* (Fig. 1). The central processing unit (CPU) or processor is the 'brain' of a computer. It contains a *control unit* and an *arithmetic* or *logic unit.* The arithmetic/logic unit performs all the necessary calculations while the control unit gives the necessary commands for all the operations in the computer system. The arithmetic unit is, in principle, like a very fast electronic desk calculator. All the operations, numeric or logical, carried out by the processor are, in a general sense, called

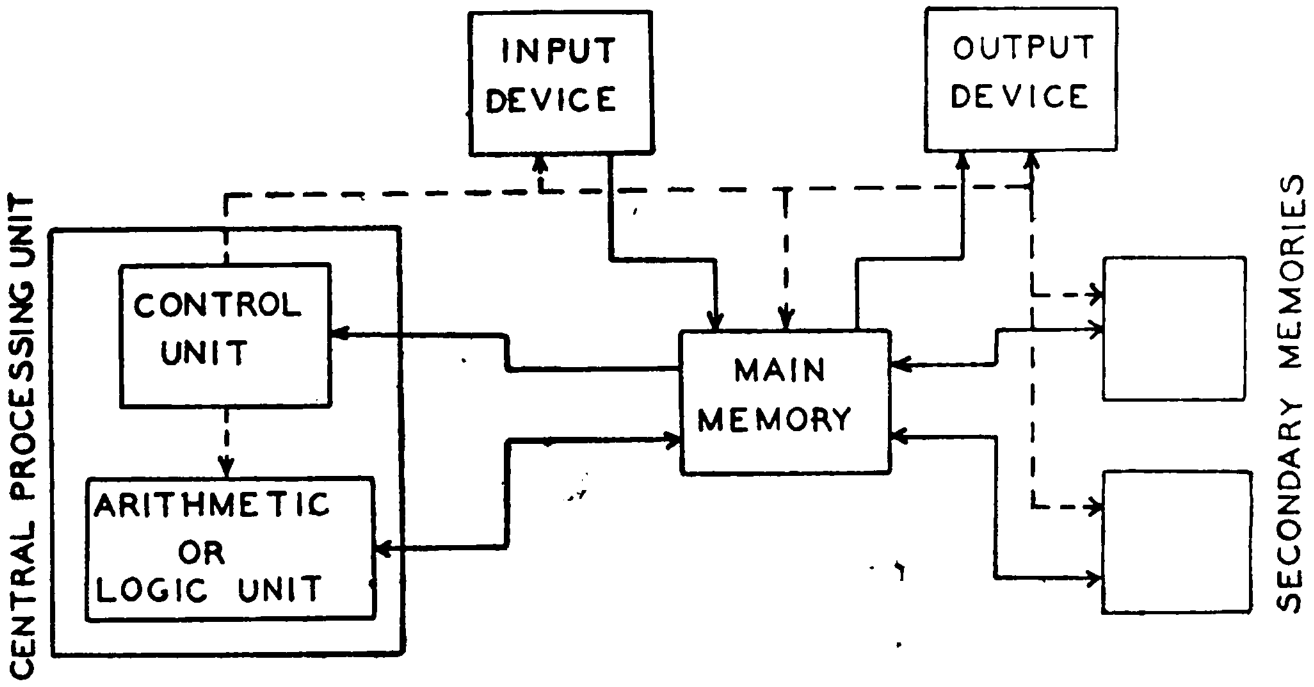


Fig. 1. The basic units of a computer system. —→ flow of data. - - -→ control commands.

computations. The memory or storage is the 'heart' of a computer. It can store any kind of information (data)—numbers, words, formulae in algebraic notation or instructions to the computer. Millions of letters and numerals can be written in the memory in a second and rubbed out. The memory can be rewritten again and again without any deterioration. Apart from the magnetic core-type main memory there are secondary memories which are mainly of the disc or magnetic tape types. These are slower but far larger. It is the memory that makes the computer an *automatic* machine. The peripherals are the 'limbs' of a computer. These are the input and output (I/O) devices. Input devices are generally card readers or paper tape readers. Output devices are line printers, card punches or plotters. The peripherals may or may not be in direct communication with the CPU, according to which the system is called *on-line* or *off-line.*

Computers work with basically simple instructions in their *machine language*, that is, the language which the circuitry of a computer can understand. The sequence of instructions given to the computer for solving a problem is called a *program.* Writing a long program in machine language is tedious and prone to error. All modern computers are, therefore, provided with *compilers* (translators) which compile or translate programs written in a carefully defined *higher level language* into the machine language. This allows a programmer to write his program in a convenient language like FORTRAN (Formula Translator), ALGOL (Algorithmic Language) or COBOL (Common Business Oriented Language). These are relatively machine-independent language. Fortran and Algol are used to write scientific and engineering programs while Cobol is for business data processing. A step-by-step computational procedure is called an *algorithm.* Compiler is itself a built-in (sub) program in the processor. A programming language has a uniquely defined *syntax* (grammer) that provides the rules for the translation. After compilation, the (translated) machine language program is *executed* to get the required results (Fig. 2). The compilation and the execution are normally done under the command of the *operating system* (OS) that is another program built in the processor.

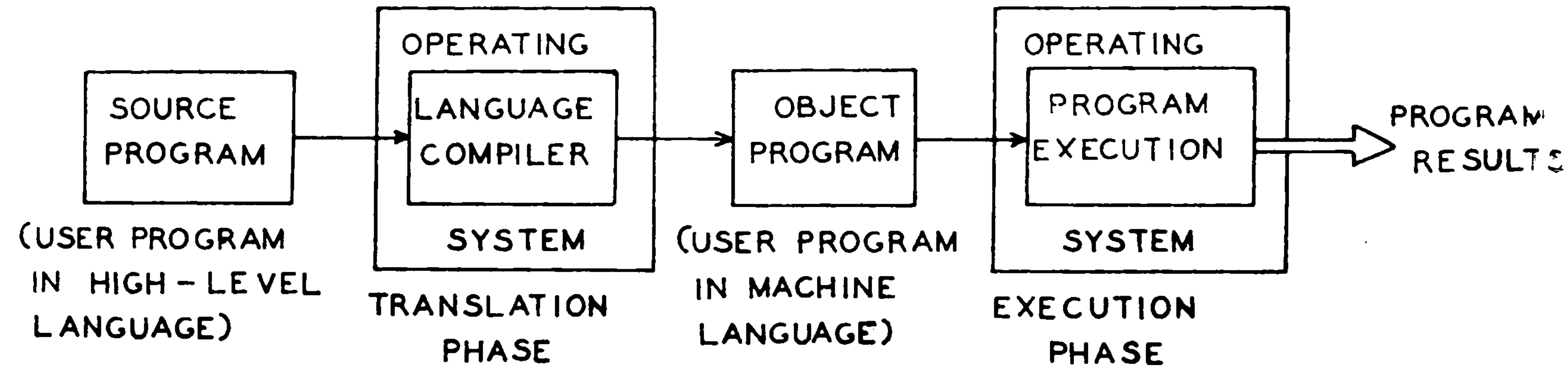


Fig. 2. Translation and execution of a source program.

As mentioned earlier, the functioning of a digital computer is based on a very simple property of electrical devices. A light bulb can be either *off* or *on*, a switch *open* or *closed*, a magnetic field in one direction or the opposite direction. If the *off* position is used to represent '0' (zero) and the *on* to represent '1' (one), an entire machine language can be buit up using these two digits. The decimal or base 10 system we use, involving numerals 0, 1, 2, ... 9, is convenient for human use. Only with the two numerals, 0 and 1, it is possible to write any given number as illustrated in Table 1. This binary or base 2 system is easily

Table 1. Binary equivalents for ordinary numbers.

Decimal System (Base 10)	Binary System (Base 2)
0	0
1	1
2	10
3	11
4	100
5	101
6	110
7	111
8	1000
9	1001
10	1010
11	1011
13	1101
14	1110
16	10000

Two Examples :

(a) 12 (decimal system) $= 1\times10^1+2\times10^0=10+2=8+4$

$= 1\times2^3+1\times2^2+0\times2^1+0+2^0$

$= 1100$ (binary system)

(b) $1111_2 = 1\times2^3+1\times2^2+1\times2^1+1\times2^0$

$= 8+4+2+1=10+5=1\times10^1+5\times10^0$

$= 15_{10}$

implemented in electrical or electronic devices. Modern computers mainly use the binary system and work with *bits* (binary digits). All the programs and routines used to operate computers are called computer *software*. This is distinct from computer *hardware* which is the computer equipment.

The need of computers in research and development programmes of a country like India is now well recognized. The Electronics Corporation of India Ltd. (ECIL) has so far manufactured a good number of small and medium range computers. The International Business Machines (IBM) Corporation of USA is taking the lead, from the very beginning, in the computer scene in India. The third generation IBM-370 computers equiped with integrated circuits (IC) are now in the market. The success or failure of an indigeneous computer depends on its software. It is software that poses a serious problem to computer users in India today. So India needs trained software people to make the best use of computers. It is perhaps not wrong to say that a computer center without a software expert is like a flower garden without a gardener.

বিজ্ঞান সাংবাদিকতায় এখনও আমরা পিছিয়ে কেন?

সমরজিৎ কর

কিছুদিন আগে আমাদের বিজ্ঞান প্রগতি নিয়ে ভারতের একজন বিশিষ্ট বিজ্ঞানীর সঙ্গে কথা বলছিলাম। আলোচ্য বিষয় ছিল এ দেশে পঞ্চাশ বছর আগের এবং আজকের বৈজ্ঞানিক গবেষণা। ওঁকে আমি প্রশ্ন করেছিলাম, দেখুন, একটা ব্যাপার কিন্তু আমি বুঝে উঠতে পারছি না। আপনারা আজ থেকে পঞ্চাশ কি ষাট বছর আগে যখন গবেষক হিসেবে কাজ শুরু করেন, জানি অসুবিধে তখন অনেক ছিল. না ছিল উন্নতমানের যন্ত্রপাতি, আসবাবপত্র, তৎকালীন বিজ্ঞান প্রগতির সঙ্গে সংযোগ রাখার মত বিজ্ঞান বিষয়ক গবেষণা পত্র-পত্রিকার আদান-প্রদানের ব্যবস্থা, এমন কি প্রয়োজন মত টাকা-পয়সাও। তবু একটা বিষয় আমার কাছে কেমন ধাঁধার মত মনে হয়। ঐ সময়কার বৈজ্ঞানিক গবেষণার দিকে লক্ষ করলে দেখা যায়, আপনারা এমন কতকগুলি বিষয়ের উপর অতিমাত্রায় গুরুত্ব আরোপ করেছিলেন, হয়ত ঐ সময়ে ওগুলি নিয়ে অত বেশি মাথা না ঘামালেও চলত।

প্রবীণ বিজ্ঞানী মৃদু হেসে বললেন, তোমার বক্তব্য ঠিকই। তবে একটা জিনিস তুমি এড়িয়ে যেতে পারবে না। বিজ্ঞানীরাও কিন্তু কম হুজুগপ্রিয় নন। অবশ্য হুজুগ কথাটা সরল অর্থেই আমি উচ্চারণ করলাম। একটু লক্ষ করলেই দেখতে পাবে, ইউরোপেও নিউটনের গতিতত্ত্বের যুগান্তকারী আবিষ্কার শতাব্দীরও ওপর উত্তরকালের বিজ্ঞানীদের এত বেশি আচ্ছন্ন করে রেখেছিল যে, যা কিছুতে তাঁরা হাত দিচ্ছেন তাঁদের ধারনা তার সমস্তই ঐ গতিতত্ত্বকে ছাড়া চলতে পারে না। শতাব্দীরও বেশি সময় ধরে রসায়নে, পদার্থ বিদ্যায়, সর্বত্র, বিজ্ঞানীরা গতিতত্ত্বের ফ্রেমে মিলিয়েই সব কিছু যেন যাচাই করতে চান। এর পর দেখ, ঊনবিংশ শতাব্দীর শেষে এল কোয়ান্টামবাদ বা অখণ্ড তত্ত্ব, এল আপেক্ষিক বাদ। ব্যাস। সেই যে শুরু হল আজও চলেছে। শুধু পদার্থ বিদ্যা নয়. রসায়ন প্রাণীবিদ্যা—সব জায়গাতেই এমন কি অর্থনীতিতেও এখন অখণ্ড তত্ত্বের ছড়াছড়ি। বিংশ শতাব্দীর মাঝামাঝি শুরু হল পরমাণু বিজ্ঞানের রাজত্ব। পৃথিবীর তাবৎ বিজ্ঞানীর চিন্তা শুরু হল পরমাণু বিজ্ঞানকে নিয়ে। এখন চলছে সলিড স্টেট ফিজিকস বা সেমিকনডাক্টারের যুগ। এবং বিজ্ঞান জগতের আপাততঃ শেষ সংস্করণ তিনটি, এক মহাকাশ বিজ্ঞান, দুই জ্যোতিপদার্থ বিজ্ঞান এবং তিন মলেকিউলার বাইওলজি বা অণু-জীববিদ্যা। অর্থাৎ আমার বক্তব্য, এক একটি সময় আসে যখন বিশেষ একটি বিষয় বিজ্ঞানীদের গতানুগতিক মনে একটা প্রচণ্ড রকমের বিবর্তন ঘটায়, তখন সর্বজনীনভাবে তাকে নিয়ে চলে ব্যাপক উৎসাহ উদ্দীপনা এবং কর্মযজ্ঞ।

মানুষের গতানুগতিক মনে যখন বিবর্তন ঘটে তখনই আসে ব্যাপক উৎসাহ, উদ্দীপনা এবং কর্মযজ্ঞ। এবং সম্ভবতঃ ভারতের বিজ্ঞান সাংবাদিকতার ক্ষেত্রেও কথাটি খেটে যায়। লক্ষ্য করুন, স্বাধীনতা পাওয়ার

পর সাংবাদিকতায় ভারতে এক যুগান্তকারী পরিবর্তন এসেছে। এদেশে এই সময়ে পত্র-পত্রিকার সংখ্যা বা প্রচার সংখ্যাই যে শুধু বেড়েছে তা নয়, বেড়েছে বৈচিত্র্যও। কিন্তু তারই মাঝে এই সে দিনও, মাত্র দু দশক আগেও একটি বিষয়ের প্রতি ভারতীয় সাংবাদিকতা সম্ভবতঃ বিমুখই ছিল। সেটা বিজ্ঞান। এর আগে যা ঘটেছে সেটা অনুকম্পারই মত। বিজ্ঞান যেন একটা ম্যাজিক। দেশ বিদেশে বিজ্ঞান সংবাদের উপর চটকদার রঙ চড়িয়ে অনভিজ্ঞ এবং বিজ্ঞান সম্পর্কে সাধারণ জ্ঞানের অভাব ছিল এমন সাংবাদিকও কিছু কিছু বিজ্ঞান বিষয়ক সংবাদ পরিবেশন করতেন। বিজ্ঞান বিষয়ক তথ্য সম্পর্কে সর্বসাধারণকে অবহিত করা, এমন একটি সদিচ্ছা নিয়ে ঐ সমস্ত সংবাদ কতকটা চুটকির মত লেখা হলেও, শেষ পর্যন্ত তারা গিয়ে দাঁড়াত ম্যাজিকের গল্পের মত। বিজ্ঞান যেন ঠাকুমার ঝুলির দৈত্যের গল্পের মত, অথবা সোনার কাঠি রূপোর কাঠি। কৌতূহল নিবৃত্তির চেয়ে পাঠকরা তাতে মজাই পেতেন বেশী।

কিন্তু প্রচণ্ড বিস্ফোরণ ঘটল, অন্ততঃ ভারতে, দু দশক আগে। মহাকাশে স্পুটনিক উৎক্ষেপন সাংবাদিকতার ইতিহাসে একটা বিস্ফোরণের মতই সংবাদ। বিজ্ঞান সর্বজনীন ভাবে কাগজের প্রথম পাতায় স্থান পেল। শুধু পেল নয় আসন প্রতিষ্ঠা করে নিল। এর পর একে একে মানুষ মহাকাশে পাড়ি দিল, চাঁদের দেশে পদার্পণ করল। কৃত্রিম উপায়ে ডি, এন, এ, সংশ্লেষিত হল, ঐ সঙ্গে জীন বা বংশানু, যা কৃত্রিম জীবন সৃষ্টির সম্ভাবনাকে বাস্তবে রূপ দেবার ইঙ্গিত বহন করে আনল। বিজ্ঞান ইতিহাসে আরও এক যুগান্তকারী ঘটনা ঘটল ষাটের দশকে মানুষ যেদিন একের হৃৎপিণ্ড অন্যের দেহে প্রতিস্থাপন করতে সমর্থ হল। অর্থাৎ, এক কথায় বলা চলে, এই প্রথম পৃথিবীর ইতিহাসে একই সময়ে তা বড় তা বড় বৈজ্ঞানিক ঘটনা ঘটতে শুরু করল। সুখের কথা আমাদের সংবাদপত্র পাশ্চাত্য দেশের মত ঐ সমস্ত ঘটনা প্রচারের ব্যাপারে সত্যিকারের একটা দুর্ধর্ষ ভূমিকা গ্রহণ করে বসল। দুর্ধর্ষ বলছি এই কারণে, এর আগে তাঁরা বিজ্ঞান নিয়ে এত বেশি কোন দিনই মাথা ঘামান নি। বেশির ভাগ সাংবাদিকই বিজ্ঞানের ব্যাপারে একেবারে অনভিজ্ঞ, বিষয়-বস্তুর সারমর্ম উপলব্ধি করার মত প্রাথমিক যোগ্যতাও তাঁদের ছিল না।

তবু বলব তাঁদের প্রচেষ্টা সফল হয়েছে। গত দশকের মধ্যে বিজ্ঞানের প্রতি জাতির একটি অনিচ্ছাভাব ছিল, সেটা কেটে উঠেছে। বিজ্ঞান সম্পর্কে একটা সর্বজনীন আগ্রহও যথেষ্ট বেড়ে গেছে। এ ব্যাপারে আরও আমাদের সাহায্য করেছে স্বাধীনতা উত্তর যুগের শিক্ষা ব্যবস্থায় বিজ্ঞান শিক্ষার বিশেষত্ব। গত দশকেই যতদূর সম্ভব স্কুলের গণ্ডীর মধ্যেও উচ্চতর বিজ্ঞানের আভাস ফুটিয়ে তোলা হয়েছে। ফলে আজ সপ্তম বা অষ্টম মানের ছেলেমেয়েদেরও রসায়ন বা পদার্থ বিদ্যার এমন কিছু কথা শিখতে হচ্ছে যার পাঠ বছর পনের আগে শুরু হত কলেজের প্রথম বার্ষিক শ্রেণীতে। ফলে প্রাথমিক যে জ্ঞান এবং অভিজ্ঞতা থাকলে কোন বৈজ্ঞানিক ঘটনার তাৎপর্য উপলব্ধি করা সম্ভব আজকের ছেলে মেয়েরা অনেক কম বয়েসেই তা পেয়ে যাচ্ছে। ফলে আজ আর বিজ্ঞান তাদের কাছে সব সময় দুর্বোধ্য বা অনাগ্রহের বস্তু রূপে গৃহীত হয় না, আমার মনে হয়, আগের তুলনায় আগ্রহ বরং অনেক গুণ বেড়ে গেছে। বিজ্ঞানের পাঠক নেই, আজ আর একথা বলা চলে না। কিন্তু তবু বলব, এ সুযোগ বাস্তব অর্থে আমাদের সংবাদপত্রগুলি এখনও পর্যন্ত গ্রহণ করতে অসমর্থ হয়েছে। কারণ কিছু আগে যে সমস্ত ঘটনার কথা বললাম তাদের ভূমিকা আমাদের জীবনে শুধু কতকগুলি উৎসবের দিনের মত। সেই বিশেষ দিন, যে দিনে ঘটা আছে, চমক আছে, আছে উদ্দীপনা, কিন্তু মুহূর্তের জন্যে। তারপর জীবনের যে রেশ, যার প্রতিদিনের ভূমিকাকে উৎসবে

পরিণত করতে পারলে জীবন সার্থক হয়, তার চেষ্টা কোথায়? মুখে বলি মানুষ বিজ্ঞানমুখী হয়েছে। বিজ্ঞান নিয়ে লেখা দরকার। অথচ তার ভূমিকা আজও সেই পাদটিকার মত। কাগজে কাগজে বিশেষ দিনে কয়েক ইঞ্চি করে জায়গা রাখা হয়েছে। মাঝে মাঝে সেখানে কিছু বিজ্ঞান বিষয়ক খবর পুরে দিলেন। কেউ হয়ত হঠাৎ একটি সারগর্ভ (?) নিবন্ধ লিখে ফেললেন, কিন্তু পাঠক-মনে তার তাৎপর্য কী দাঁড়াতে পারে সে সম্পর্কে কোন চিন্তাই তাঁর নেই। হয়ত বা রয়টার এবং পি, টি, আই-এর দেওয়া আধা বিকৃত বৈজ্ঞানিক তথ্যকে চটকদার করতে গিয়ে আরও খানিকটা বিকৃত করে সকলের যাতে চোখে পড়ে তার জন্যে বক্সের মধ্যে প্রকাশ করা। ব্যস, হয়ে গেল বিজ্ঞান সাংবাদিকতা।

খানিকটা অপ্রসাঙ্গিক হলেও একটা কথা এখানে বলে রাখি, ইস্কুলের ছেলেকে যখন আমরা বলি, 'যে বিষয় বিশেষ জ্ঞান জোগায়, তাকে বিজ্ঞান বলে'—ভুল আমাদের সেখান থেকেই। কারণ ওর সঙ্গে আর একটু কথা আমাদের জুড়ে দেওয়া উচিৎ ছিল, ঐ জ্ঞানের সঙ্গে জীবনেরও সম্পর্ক আছে, সম্পর্ক আছে মানুষের ভাল লাগার, মন্দ লাগার, তার হাসি, কান্না, আনন্দের। এবং এটা আছে বলেই শ্রোডিঞ্জারের শক্তিস্তরের সমীকরণ যত না সর্ব সাধারণকে দোলা দেয়, তার চাইতে হাজার গুণ আকর্ষণ করে মানুষের চন্দ্র অভিযান। কেন? না এর মধ্যে যতই বড় বড় তত্ত্ব বা প্রযুক্তিগত কারসাজি লুকিয়ে থাক, তার চাইতেও বড় কথা যুগান্তকরী এই অভিযানে মানুষ তার দেহ, মন সমস্ত কিছু নিয়ে জড়িয়ে পড়েছিল, তাই। জটিল এই বিজ্ঞানও সাধারণের মনে প্রচণ্ড আগ্রহের সঞ্চার করেছিল, কারণ মানুষ নিজে এতে ইনভলভ্‌ড ছিল। আর এই কারণেই হৃদপিণ্ডের প্রতিস্থাপন বা ডি, এন, এ-র ব্যাপারে সে আগ্রহী হয়ে ওঠে—কারণ এখানেও মানুষ বিশেষ জ্ঞান ছাড়াও তার ব্যক্তিগত নিরাপত্তা বা স্বার্থের সন্ধান পেয়েছে। এ সব কথা বলার উদ্দেশ্য, বিজ্ঞানের যে সমস্ত উদ্ভাবনার সঙ্গে জন-সাধারণ নিজেদের পাশাপাশি দেখতে পায়, তাদের আমলই তাদের কাছে বেশি। সাংবাদিকের দায়িত্ব এ ধরণের খবরগুলিই 'একসপ্লয়েট' করা।

একথা ঠিক রোজই চাঁদে যাওয়ার মত কোন ঘটনা ঘটবে না, অথবা এনজাইম তৈরির মত কোন অবিশ্বাস্য ব্যাপার। এসব ক্ষেত্রে পাঠককে কোন সংবাদ পড়াতে হয় না, সে নিজে থেকেই আপন আগ্রহের তাগিদে পড়ে নেয়। সাংবাদিকের দায়িত্ব এখানে কম। কিন্তু বিজ্ঞান সাংবাদিকতা বজায় রাখতে গেলে বেশির ভাগ ক্ষেত্রেই সংবাদ তৈরি করতে হবে এমন ভাবে যা পাঠকের মনে সাড়া জাগায়, যার বিষয়বস্তু তার ব্যক্তিগত আশা আকাঙ্ক্ষার সঙ্গে সম্পর্কিত এবং সে সংবাদ তার চোখ এড়িয়ে না যায়।

এ এক গুরুত্বপূর্ণ দায়িত্ব। এবং পরিতাপের বিষয় সে দায়িত্ব পালনে আমরা প্রচণ্ড অবহেলারই পরিচয় দিয়ে এসেছি। ভারত স্বাধীন হল। দেশে একের পর এক পরিকল্পনা রূপায়িত হল। হচ্ছেও। বড় বড় গবেষণাগার, কলকারখানা, চিকিৎসা কেন্দ্র অথবা কৃষি বিষয়ক গবেষণার কেন্দ্র তৈরী হল। বর্তমান লেখকের আমেরিকা যুক্তরাষ্ট্রের আধুনিকতম গবেষণাগারে কাজ করার সৌভাগ্য ঘটেছিল। সেই সঙ্গে সে দেশের কয়েকটি কারখানা বা বিশ্ববিদ্যালয়ের গবেষণাগার। তারপর বিজ্ঞান সাংবাদিকতা করতে গিয়ে এদেশেও কিছু কিছু গবেষণা কেন্দ্র বা কল কারখানা দেখার সৌভাগ্য ঘটেছে। এবং তুলনামূলক ভাবে মনে হয়েছে কোন কোন ক্ষেত্রে এ দেশ পৃথিবীর যে কোন উন্নত দেশের সমতুল্য। কৃষি গবেষণায় ভারত যে নজির স্থাপন করছে, এত বাধা বিঘ্নের মধ্যেও, পৃথিবীতে তা খুবই বিরল ঘটনা। চিকিৎসা বিজ্ঞানেও ভারতের ভূমিকা আজ বিশিষ্ট। দুর্গাপুরের ইস্পাত কারখানার রোলিং মিল অত্যন্ত আধুনিক এবং শিল্পক্ষেত্রে

অত্যন্ত লাভজনক। এ সমস্ত ব্যাপারের সঙ্গে দেশের অর্থনৈতিক সম্পর্কও জড়িত। অথচ আমাদের সংবাদপত্রে এরা প্রায় উপেক্ষিতই বলা চলে। দুর্গাপুরের ব্লাস্ট ফার্নেস ভেঙ্গে পড়লে বা ধর্মঘট হলে খবর বেরোয় প্রথম পাতায়, অথচ একটা ব্লাস্ট ফার্নেসের সত্যিকারের ভূমিকা কী, একবার তা অচল হয়ে পড়লে, তা সে যে কারণেই হোক, সামগ্রিক ক্ষতি কি বিপুল পরিমাণ দাঁড়াতে পারে এটিকে আমরা খবর বলে মনে করি না। কাগজ খুললেই আমরা দেখতে পাই, আজ শিয়ালদার ট্রেন চলল না। সঙ্গে সঙ্গে জ্বালাময়ী সম্পাদকীয় বেরোল 'প্রশাসনিক দুষ্টি'র অনুসন্ধানে। একেবারে একতরফা বিচার। অথচ অত্যন্ত জটিল ঐ রেল ব্যবস্থায় যাত্রীদেরও যে একটা বিশিষ্ট ভূমিকা রয়েছে সে খবর আমাদের কম লোকই রাখেন। যান্ত্রিক ব্যবস্থাকে নিজেদের স্বার্থে কাজে লাগাতে কী কী দায়িত্ব আমাদের পালন করা দরকার—তার জন্যে যে যান্ত্রিক অভিজ্ঞতা—শক্ত কিছু নয়, সাধারণই—সে সম্পর্কে কোন তথ্যই খবরের কাগজে লেখা হয় না। ফলে আমাদের ডাক্তারদের সঙ্গে শুধু ঝগড়া বা বিতণ্ডা করেই সময় কেটে যায়, মুমূর্ষু রোগী আরও বেশি মূর্চ্ছিত হয়।

অর্থাৎ মোদ্দা কথা হল এই, যান্ত্রিক প্রগতিকে যখন আমরা বেছে নিয়েছি, সেই যন্ত্রের সঙ্গে সর্বসাধারণকে পরিচিত করে দেওয়ার একটা মস্ত বড় ভূমিকা অবশ্যই সংবাদপত্রের। বিশেষ করে আঞ্চলিক ভাষায় যে সমস্ত পত্র প্রকাশিত হয় তাঁদের। কারণ তাঁদের পাঠক সংখ্যাই সর্বসাধারণ। সংখ্যায় তাঁরাই অগ্রজ প্রতিম। এতে করে অন্ততঃ দুটি বড় রকমের সমস্যার আমরা সমাধান করতে পারব। এক, দেশবাসী তাঁদের সামগ্রিক বিজ্ঞান, শিল্প এবং কারিগরি উদ্ভাবনা সম্পর্কে সম্যক পরিচয় পাবেন। তাঁদের অনেক কিছুই যে অকিঞ্চিৎকর নয়, এটা তাঁরা উপলব্ধি করতে পারবেন। 'ফরেইন' মানেই যে সব সেরা নয় সে ভুল ভাঙ্গবে। নিজেদের ভাল জিনিসগুলি সম্পর্কে অবহিত হতে পারলে এই সঙ্গে আত্মবিশ্বাস এবং স্বদেশী উদ্যমের প্রতি মমত্বও বাড়বে। দুই, দেশের বিজ্ঞান, কারিগরি এবং শিল্প উদ্যম সম্পর্কে তাঁরা আরও বেশি দায়িত্ব সম্পন্ন হতে পারবেন।

এবং বিজ্ঞান সংবাদিকতাকে পরিপুষ্ট করার এটাই মাহেন্দ্রক্ষণ। কারণ দেশের মানুষ আজ বিজ্ঞান সম্পর্কে অনেক বেশি আগ্রহী হয়ে উঠেছেন।

এখন দেখা যাক বিজ্ঞান সাংবাদিকতাকে বিকশিত করার ব্যাপারে মৌলিক বাধা কোথায়?

(এক) সংবাদপত্রের কর্তৃপক্ষদের বক্তব্য, উপযুক্ত লেখকের অভাব। কথাটা অমূলক নয়। কারণ বিজ্ঞান যাঁরা বোঝেন, তাঁদের মধ্যে ভাষার অভাব। সর্বসাধারণের মত করে ব্যক্ত করার কৌশল অনেক ক্ষেত্রে যথাযথ নয়। যাঁর হাতে ভাষা আছে তিনি বিষয়বস্তু সম্পর্কে অপটু।

(দুই) বৈজ্ঞানিক তথ্য পরিবেশন করার দায়িত্ব যাঁদের হাতে, বিশেষ করে ভারতে, তাঁদের সহযোগিতা বেশির ভাগ ক্ষেত্রেই কাজে আসে না। তাঁদের কাছ থেকে স্পষ্ট এবং সঠিক ধারণা, যার উপর নির্ভর করে সাংবাদিকরা কাজ করতে পারেন—খুব কমই পাওয়া যায়। লক্ষ লক্ষ টাকা খরচ করে বিভিন্ন কারিগরি, শিল্প বা বিজ্ঞানসংস্থা যে সমস্ত তথ্য পরিবেশন করেন তাতে আসল বক্তব্য (যা সর্বসাধারণের মধ্যে প্রচার করা যায়) খুবই অস্পষ্ট।

(তিন) লেখকদের মধ্যে নিয়মিত সংগঠন মূলক কোন বৈাজ্ঞনিক কাজকর্মকে 'নিউজভ্যালু'তে পরিণত করার জন্যে যতটা মননশীলতা থাকা দরকার, তার অভাব।

(চার) বেশিরভাগ ক্ষেত্রেই ধরে নেয়া হয়, বিজ্ঞান কি আর সাধারণ মানুষ বুঝতে পারবে? 'আগ বাড়িয়ে এই ভাবে চিন্তা করার ফলে প্রাথমিক কাজ শুরু করাটাও অনেক সময় কঠিন হয়ে পড়ে।

(পাঁচ) বিষয়বস্তুকে আকর্ষণীয় করে তোলার যে কল্পনা, বিজ্ঞান এবং জীবন সম্পর্কে সম্মিলিত বোধ, তার অভাব। ইত্যাদি, ইত্যাদি।

সমস্যার সমাধানের ব্যাপারে কিভাবে আমরা এগোতে পারি?

(এক) নিয়মিত যাঁরা বিজ্ঞান নিয়ে লিখছেন তাঁদের উৎসাহ দেওয়া।

(দুই) বিশেষ আন্তর্জাতিক মর্যাদা সম্পন্ন বিজ্ঞান বিষয়ক সংবাদ ছাড়া দেশের খবরের উপর বেশি গুরুত্ব দিতে হবে। এপ্রসঙ্গে আপাতত যাঁরা বিজ্ঞান সাংবাদিকতায় যথেষ্ট অভিজ্ঞতা অর্জন করেছেন, তাঁদের উচিৎ হবে দেশের বিভিন্ন বিজ্ঞান, শিল্প এবং কারিগরি বিশেষজ্ঞদের সঙ্গে নিয়মিত যোগাযোগ রেখে কোথায় কি ঘটছে সে সম্পর্কে অবহিত হওয়া।

(তিন) বিজ্ঞানের সেই সমস্ত বিষয়ের উপর বেশি জোর দিতে হবে যার সঙ্গে দেশবাসীর সম্পর্ক অত্যন্ত ঘনিষ্ঠ।

(চার) নিয়মিত বিভাগ খুলে তরুণ বিজ্ঞান লেখকদের অভিজ্ঞতা বাড়ানোর ব্যাপারে সাহায্য করা।

(পাঁচ) প্রাত্যহিক সংবাদের সঙ্গে কিছু কিছু বিজ্ঞান সংবাদ পরিবেশন। এতে করে পাঠকরা যে শুধু দেশের বিজ্ঞান প্রগতির সঙ্গে 'সাম্প্রতিক প্রত্যক্ষ' যোগাযোগ রাখতে সমর্থ হবেন, তাই নয়, বড় বড় সন্দর্ভ পড়ার ক্লান্তি থেকে মুক্তি পাবেন, অথচ বৈজ্ঞানিক খবরাখবর পড়ার অভ্যেসও বাড়বে।

(ছয়) বিষয়বস্তুর বিস্তৃতি। বিশেষ করে সেই সমস্ত বিষয় যেমন ভূ-তত্ত্ব, মানব বিজ্ঞান, সমাজ বিজ্ঞান, নৃতত্ত্ব প্রভৃতি যাদের সম্পর্কে সচরাচর কোন কথাই বলা হয় না, জীবনের মূল্যায়নে যাদের ভূমিকা অপরিহার্য।

(সাত) শিল্প এবং কারিগরি বিষয়ক রচনা বিশদ এবং অত্যন্ত সতর্কতার সঙ্গে রচনা করতে হবে। যেমন ধরুন, দুর্গাপুরের রোলিং মিল অথবা ব্যাণ্ডেলের তাপবিদ্যুৎ উৎপাদন কারখানা। দেশের লোক আজও জানেনা যে এদের কারিগরি জটিলতা, অন্যান্য শিল্প তথা অর্থনৈতিক ক্ষেত্রে এদের প্রভাব, একবার এগুলি অচল হলে কী কী ধরনের যান্ত্রিক এবং প্রযুক্তিগত অসুবিধে ভোগ করতে হয় এবং তার কি পরিণতি হয় ইত্যাদি।

(আট) বিশ্ববিদ্যালয়ের স্তরে বিজ্ঞান সাংবাদিকতার উপর পঠন এবং গবেষণা চালু করতে হবে।

পরিশেষে একটি কথা বলব। দুর্ভাগ্য বশত এদেশে আর কোন মাধ্যম না থাকায় একমাত্র সংবাদপত্রই আজ এখানে লোক শিক্ষার মাধ্যমে রূপে চলে আসছে। ফলে তার কণ্ঠস্বরেই আজ জনগনের কণ্ঠ নিমজ্জিত। তার ভাবনা এবং কল্পনাই এখন জনশিক্ষা। অতএব বিজ্ঞান চেতনা ও সম্প্রসারণের ব্যাপারে প্রাথমিক দায়িত্ব তাকেই নিতে হবে। বিজ্ঞান প্রচারের মত গুরুত্বপূর্ণ কাজও।
