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CEYLON ASSOCIATION

FOR THE

ADVANCEMENT OF SCIENCE

PART II

PROCEEDINGS

OF THE

TWENTYSIXTH

ANNUAL SESSION

18th to 21st December, 1970

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CONTENTS—PART II

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The Ceylon Association for the Advancement of Science

15th December 1970

Inaugural Address

by

THE HONOURABLE PIETER KEUNEMAN,
Minister of Housing and Construction

Permit me, first of all, to thank the Ceylon Association for the Advancement of Science for inviting me to make the opening speech at your 26th annual sessions.

In the past quarter of a century, your Association has grown from modest beginnings to a position where it covers many branches of scientific activity and commands great respect and authority, both in Ceylon and abroad.

The task that I have to undertake today should really, and more appropriately, have been fulfilled by my colleague, the Minister of Industries and Scientific Affairs. But as he had to leave suddenly to represent the Government of Ceylon at an important conference abroad, I have had to fill in as his understudy.

I am acutely conscious of my inadequacy to sustain the honour you have done me. My acquaintence with the natural sciences and technical processes is very sketchy. Such disciplines as I have been exposed to are connected with the social and historical sciences, and with the humanities. So, if I seek to express some random thoughts about the problems of science and scientists in Ceylon, I trust you will extend to me both understanding and compassion.

The world today is in the midst of a great scientific and technological revolution that is even more epoch-making than the Industrial Revolution of the 18th and 19th centuries. There has been a tumultous growth in the key branches of science and technology, especially physics, chemistry, engineering and energetics. The development of the old branches of knowledge has been accelerated, and new branches such a nuclear physics, missiles engineering, cybernetics and computing techniques, quantum electronics and lassers, space research and so on have been produced.

In technology, too, conditions are being created for a leap in the productive forces. The Industrial Revolution of the 18th and 19th centuries, metaphorically speaking, transformed some of the implements of labour from the hands of men to the hands of the machine. Today, manual and semi-manual labour and separate, relatively simple machines connected with each other into shops and plants, which were the summit of the development that began with the earlier industrial revolution, are giving way to automated systems of machines, embracing whole branches of industrial activity.

The contemporary scientific and technological revolution, which proceeds under the conditions of, and is profoundly influenced by, the competition between capitalism and socialism on a world scale, also has a tremendous impact on politics, ideology, international relations and the science of warfare. It transforms the nature of productive labour, as well as management. It invades the spheres of culture, living conditions and recreation and brings about far-reaching changes in the systems of information and communications. It is making science itself a direct productive force.

The deep-going and dramatic changes that the contemporary scientific and technological revolution produces in the life of mankind are, of course, not without negative features.

In some advanced capitalist countries monopolies have used the new potentialities to maximise profits, intensify the exploitation of labour, and even to swell the ranks of the unemployed.

A far more dangerous development has been the militarisation of science, when the lion's share of allocation for science is spent on military research and the perfection of weapons of mass destruction.

Although the scientific and technological revolution has generally by-passed the countries of the Third World, its effect on these countries has been unfavourable. The gap between these countries and the developed countries has become more marked. The foreign exchange that these countries earned from the export of traditional raw materials has diminished as a result of competition from new synthetic substitutes. The unequal position that the countries of the Third World occupy in the international division of labour has become greater.

All this has, on the one hand, led to renewed and quite unjustified prejudice against science and the scientists.

Questions are often asked why so much money is devoted to space research, when millions are starving, or why computer science should be encouraged when it can deprive men of the wo rk they now perform. And the mad scientist who wants to destroy the world has become a stock villain of horror films and fiction.

In a healthy reaction against such narrow, misinformed and misplaced prejudice, which seek to make scientists the scapegoat for the misdeeds of those who misuse their discoveries, many scientists have begun to re-think their social role.

They have begun to speak up for peace, for the prohibition of weapons of mass destruction, for the peaceful uses of nuclear energy, and for exclusive use of science for its fundamental purpose namely, the elucidation of the basic laws and objective processes of natural and social development, and their application for the betterment of Man.

The scientists of Ceylon are only a very small fraction of the two million scientific workers in the world today. They, too, have important conclusions to draw from what is happening in the world and in their own country in regard to the role of scientists in society.

In the extremely complex, many-sided and ramified social phenomenon that is modern science, the factors that tended in the past to separate the pure from the applied sciences, the natural from the social sciences, and science itself from technology are rapidly ceasing to have the validity, if any, that they had. The need for a multi-disciplinary approach to scientific research and development is one of the main lessons that have to be learnt from the contemporary development of science and from our own situation.

As Ceylonese, we can be justly proud that one or two of the scientists that our country produced have been able, while working abroad, to contribute towards international scientific progress. We are even more proud of those who, working here at home, under very much more difficult and limited conditions, have helped to deepen and clarify the understanding of general scientific problems.

But what I should like to ask is : what should be the basic direction of our scientific work now and in the period immediately ahead ?

With all due respect to the genuinely creative efforts at fundamental research, I think we must face the fact that, by and large, we have neither the need nor the financial or technical capacity to compete in this sphere, Such research work of a fundamental nature as we can afford to undertake should provide a take-off base for research projects of economic importance to our country and its people.

A major contradiction that confronts us today is that material advancement has lagged far behind the expectations of the mass of our people, and especially the youth who form nearly 55% of the population.

We cannot blame them for impatience when, nearly a quarter of a century after we are said to have become independent politically, we are still fiddling gingerly with the fringe of basic problems of our deformed and stagnant economy such as unemployment, land reform, poor living standards, an acute shortage of houses, low productivity and a lack of managerial skills.

It is not their fault if, in the search for solutions to these problems, we have not yet been able to make the necessary structural and institutional changes, mobilise our natural and human resources rationally and scientifically, and draw from the vast fund of knowledge and expertise accumulated by the revolution in science and technology what we want and can usefully apply to our own conditions.

The central problem of bridging what I would call the " expectancy gap " and starting to catch up with the developed countries as rapidly as possible, is not one that can be left to politicians and administrators alone. A major role has also to be played by the scientists and technologists, because the state of economic development of a country is closely related to its scientific activity.

The United Front Government has realised this fact, and has already taken several significant steps to see that scientists, engineers and others of similar disciplines are actively associated with the Administration, with economic planning and with the processes of decision-making.

Our Government is anxious to see that there is a greater co-ordination between the research work that is being done at the moment at the universities, research institutes, government departments and industrial enterprises. I am aware that the Minister of Industries and Scientific Affairs is anxious to see the National Science Council play a more dynamic role in this matter.

We are also anxious to expand the areas of scientific research and to encourage more specialised research in certain branches. Up to now, the main emphasis given by our specialised research institutes was to the problems of our three main export crops, of paddy production and of public health. Much distinguished and useful work has been done in all these fields. But it is not enough.

My colleague, the Minister of Lands, is, at the moment, at work on setting up institutions to research into varied agrarian problems. My own Ministry of Housing and Construction has received cabinet approval to set up an institute to research into local building materials and their uses, building techniques and other problems of our construction industry.

The Minister of Industries and Scientific Affairs has a number of such proposals under study. One of them, which was proposed by the Geology Department of the University of Ceylon, is for a crash programme of geological exploration.

The minister is also anxious to see more work done on the use of agro raw materials for the manufacture of industrial products. Research into how to improve the quality of products manufactured in Ceylon and the development of new techniques are also fields where more useful work can be done. The minister has already indicated that he has such aims in view in his proposals to reorganise and expand the work of the Ceylon Institute of Scientific and Industrial Research.

The by-products of the Ceylon Petroleum Refinery will also provide us with new primary raw materials to produce various chemicals, plastics and man-made fibres.

There is such a lot to be done that we cannot really afford to encourage "elite-ism" or a mandarin outlook in our research work. Most of this research work is being paid for out of public funds and the scientists themselves are the product of a free education scheme whose cost has been borne by the community at large.

In choosing research projects, therefore, the main criterion that should guide our scientists is whether this research will directly benefit the economic development of the country and the social progress and well-being of its people. Considerations such as whether the subject chosen for research is of current interest in the advanced countries or whether the project could lead to the publication of a paper in an international journal should not be the main ones.

I should like to tell the scientists that their contribution to this country will be judged not by the number of research papers published but by the degree to which their work leads to the discovery of new raw materials and the better use of existing ones ; and to the extent to which it increases productivity, improves the quality of local products, reduces waste and improves the health and well-being of the nation.

This will not only require new thinking in several existing research institutes, but also a new approach to scientific research at the universities.

I regret to say that scientific research at the universities has not yet had any marked impact on the people at large. One cannot escape the impression that this body of research has not been properly organised and that its results are small. Of course, this is due, in large measure, to the fact that our universities are regarded primarily as teaching, rather than research, institutions. University scientists are burdened by excessive teaching duties and hampered by lack of funds and modern research equipment.

I am sure that this position will change with the efforts that the Minister of Industries and Scientific Affairs is now making to see that university scientists are drawn into development research and to provide them with grants for special research projects.

We shall also have to change the character of science education in our schools which is, at present, geared more to producing science teachers than future scientific workers.

And we shall also have to give serious thought to evolving ways and means by which the results of scientific research can filter down to the levels of the technician, the skilled workman in the factory and the farmer in the field.

As far as technology is concerned greater attention can well be paid to the question of the technological levels that are relevant to our contemporary situation. The most sophisticated techniques, which may be excellent in the advanced countries, can have social consequences quite opposite to what are intended if they are uncritically introduced and applied in countries like Ceylon. Advanced technology also calls for advanced servicing, which itself creates new problems. The search for intermediary technologies, which correspond to existing levels of productive development, expertise and labour consciousness, and which are capable of being built upon and further advanced, can usefully be kept in the forefront of our minds.

It is not an easy task to adapt and reshape to our needs techniques that have been developed elsewhere to meet situations dissimilar to ours in many ways. But I firmly believe that our scientists and technologists have the ability to carry out this essential task.

Ladies and Gentlemen; I hope that I have not trod on any toes, bumped against any sacred cows, or dropped too many bricks. These random thoughts from a non-scientist minister are intended

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only to provoke discussion on some of the problems that our scientists have to face and the role that they have to play in the forward march of the nation.

I can assure you that the United Front Government values our scientists highly and is anxious to enlist their help and co-operation in fulfilling the mandate which the people gave us. I am sure that the 26th Annual Sessions of your Association will add new lustre to its name and help the Government and people of our country in seeking solutions to the many problems that confront us.

I wish your work every success.

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General President's Address

SOME CONTRIBUTIONS TO ENGINEERING RESEARCH AND DEVELOPMENT IN CEYLON*

by

A. N. S. KULASINGHE

INTRODUCTION

Research and Development (R & D) in any field can be carried out only if there is a climate which is sympathetic towards such work. In the days prior to Independence such work was encouraged only in the area of agricultural development especially in relation to the production of commodities like tea, rubber and coconut, which could be sold for the benefit of the country that ruled Ceylon. Industrial R & D was not encouraged but probably discouraged in view of the effect such development would have had on the traditional market in Ceylon for manufactured goods from countries like Great Britain. The emphasis was on the growing of crops like tea, rubber and coconut which were required by these countries. The advice given to us even in relation to manufacture of products based on rubber was that it was much better for us to buy them from the developed countries enabling them to buy our rubber cheap and sell manufactured goods to us at high prices. Even the manufacture of tyres was considered uneconomical.

It is no wonder, therefore, that Engineering R & D did not have much of a chance during the period prior to Independence. This type of thinking persisted for some time, even after Independence. This situation was aggravated by the fact that some of those holding key positions in government administration were ignorant of the value of research and development. Some were even hostile to such work due to their ignorance and their desire to keep out scientists and technologists from positions from where the thinking of the politician could be

* Delivered on 15th December 1970

influenced. They were helped in this process by advisers from abroad who were opposed to Engineering R & D due to their vested interests. I remember the occasion when a foreign engineer who was in charge of a large mechanical engineering department refused to make a simple manually operated reinforcing bar bender on the ground that his department was not a manufacturing firm. His idea was to import even such simple things from the home country. I am sure this gentleman will receive a rude shock if he visits Ceylon now.

One of the grave mistakes committed by some workers in many fields of R & D in a country like Ceylon has been to postpone such work till the ideal facilities become available. This is a great mistake for a developing country where such resources are bound to be meagre. It would also take a long time for such facilities to reach the standards obtaining in developed countries. It is therefore an absolute necessity that we start work with whatever facilities that are available and develop more refined methods and equipment as the work proceeds. This is specially so in engineering R & D and the work which I propose to deal with will illustrate this point.

From the studies that I have carried out during my engineering career of thirty years, I find that the most urgent areas where R & D work is necessary are in developing uses of locally available raw material, especially the utilisation of waste products from our traditional industries. The production of the necessary equipment for local industries is also an essential requirement if some of our industries especially those using local raw materials are to be successful. The dependence on imported equipment for such work can make a good industry uneconomical. It is well known that the cost of manufacture of most products depends to a large extent on the cost of plant and equipment used. It has been my experience that much of the equipment which is imported now can be made locally provided sufficient R & D work is undertaken by those who possess the basic knowledge required for such work. This work has, however, to be undertaken with devotion and tireless application.

There are a number of other fields where R & D work has to be undertaken to ensure the progress of our country without continuing to be in the stranglehold of developed countries. The development of forms of construction making more economic use of imported materials and the greater utilisation of local materials is one such field. There are a number of areas where traditional methods are wasteful of material.

There are also areas where certain types of work are believed to be practicable only in the developed countries. This applies especially to certain sophisticated equipment which is required for some of our industries. I think that this aspect requires very careful examination, as my experience is that devoted hard work can get over a lot of the problems which appear too complex and which appear to require sophisticated technology. In a number of these cases, facilities available in the country can be adapted for such work successfully. This will be made apparent from some work described later in this address.

I will now go on to describe some R & D work with which I have been associated. A large amount of this work has not been recorded elsewhere and I have taken this opportunity as a suitable one for this purpose. They will be grouped according to the field of engineering to which they belong.

Concrete Structures

A considerable amount of my work during the early stages of my career was devoted to problems connected with concrete structures. This was a natural outcome of my early training combined with the problems that faced me in the course of my work at the Colombo Port Commission.

The problem of corrosion of steel reinforcement in R.C. structure in the Port and their failure due to such corrosion was an urgent problem. The use of prestressed concrete was an obvious solution but the general lack of information on this subject at that time (1948) and the difficulties of communication with workers in this field in Europe made it necessary for a large amount of development work to be undertaken before this material could be used with confidence. Stressing techniques and equipment had to be developed and this resulted in an entirely new system of post-tensioning being developed in 1954, although the first structures in prestressed concrete were built in 1949. This system of prestressing uses a mild steel anchorage made possible by stressing this material to such a point where plastic flow occurs. It is a departure from the use of High Tensile Steels used in most systems except in the case of the Fressymet system which uses concrete stressed to create plastic flow. A study of the normal operations carried out in prestressing resulted in the development of a stressing jack in light alloy which incorporated the operations of stressing, anchoring and de-wedging.

The developments in prestressed concrete led to further development in structural engineering. One such development is the system of piling and cylinder sinking for maritime structures. The system incorporated certain novel features. They were :—

1. The use of precast hollow sections joined together by prestressing.

2. The use of water for removing the excavated material from inside the pile with the use of an " air lift " pump.

3. The use of a hollow pneumatic hammer for driving, enabling the " air lift " to operate through the hammer.

4. The floating of the hollow cylindrical piles to position and the method of handling them.

In the field of large-span concrete roof structures it is worth mentioning the development of :—

1. Precast cylindrical shell roofs constructed by assembling precast sections by an orthogonal system of prestressing. This is carried out at ground level and the complete shell jacked up to the required height.

2. The precasting of long saddle shaped hyperbolic paraboloid shells on the long lines system of prestressing.

3. The introduction of edge prestressing to umbrella shaped hyperbolic paraboloid shells to correct corner droop.

4. A highly efficient concrete north light truss for factories.

In concrete structures a very important development has been the use of concrete with randomly oriented pieces of steel wire for the construction of concrete boats. This material was developed by us at the State Engineering Corporation R & D Laboratories and later used in the construction of fishing boats in place of the type of construction introduced by Nervi. This material ' wirecon ' as we call it, along with one layer of wire mesh is adequate to resist the stresses in a concrete boat. It is faster and cheaper than the ' ferro-Cemmento ' of Nervi which consists of a number of layers of mesh with the mortar forced through them during the plastering process.

I need not stress the advantages of concrete boats especially for an island like Ceylon which is in need of a large number of boats every year for its fishing fleet. The cost of a concrete boat is less than 75% of its equivalent in timber, and it is much stronger, requires less attention and requires no expensive sheathing. The cost advantage and speed of construction are much greater in the case of boats larger than the $3\frac{1}{2}$ ton class. "Wirecon" is the result of work directed towards the replacement of asbestos fibre for reinforcing cement based products.

Developments in the use of local raw material

Clay, as used in the manufacture of traditional building materials like bricks and tiles is a material which is found in abundance in Ceylon. Very fine examples of clay products are to be found in buildings put up more than two thousand years ago in places like Anuradhapura. There has been, however, no change in the products like roofing tiles for nearly a century. The flat roofing tile produced today is the same as the Calicut tile which was used during the time of our grandparents.

My attention was particularly drawn towards the better utilisation of clay, when the brick and tile manufacturers in this country agitated for a drastic curtailment of the ban on the import of asbestos fibre without trying to improve the range of clay products.

The shortage and high cost of timber has been a deterrent against the use of clay roofing tiles. Asbestos cement roofing sheets have been used at an increasing rate although the latter does not provide the same living comfort in a house. Work which started about 3 years ago on the development of a long-span clay roofing tile comparable to the asbestos cement corrugated sheet has been successful and a roofing tile 4′-6″ long and 1 ft. wide able to span 4 ft. is now under production.

A large number of problems had to be solved. The fired clay tile similar in cross section to a corrugated asbestos sheet is reinforced by grouting in strips of treated timber to carry the load specified by the British Standard Specification for asbestos cement sheets. Much higher strengths have been achieved and loads as high as 650 lbs. per ft. width have been carried at mid span of 4 ft. The weight per sq. ft. of roof covered is not more than that for Calicut tiles without taking into account the extra timber involved in the latter. The cost per sq. ft. of roof is about half that of corrugated asbestos cement roofing sheets. The insulation value is, of course, far superior to the corrugated asbestos sheets.

The R & D work in the development of another very useful item, has been roof purlins made up of hollow clay blocks joined together by prestressing. Purlins for 10 ft., 15 ft., and 20 ft. spans are being produced on a regular basis and used on a number of important projects. These purlins save about 40% on the cost of timber purlins although it is far superior to timber in durability and fire resistance. The use of clay purlins and long clay tiles result in the cost of a roof being reduced to half that of one with asbestos cement corrugated sheets on timber purlins.

Another application of fired clay products is the room sized wall panel made up of hollow clay blocks set in a thin concrete frame. This is much cheaper and lighter than a concrete panel and gives a higher thermal insulation.

Much R & D effort has been put into the use of coconut fibre waste which can be seen in mountainous heaps at fibre mills. It has been a very big problem in waste disposal as it takes a very long time to deteriorate, is not attacked by termites and does not burn easily.

A product like hard board had been made on an experimental basis using a synthetic resin as a binder. The cost of the synthetic resin binder makes this process uneconomical and our efforts were directed towards using a cheaper binder, or mobilising the natural binding materials present in the fibre waste itself. The use of Portland cement as a binder has been quite successful, but further work has resulted in bringing out the natural binder present in the material for this purpose. This is achieved by applying the correct pressure and temperature. This work was facilitated by the development of hot presses of high capacity using prestressed concrete in their construction. The results would have been different if the work depended on imported hot presses. It has been possible to produce soft boards of high insulating value which can replace asbestos cement flat sheets, at a much lower cost. These boards can be used for partitions as well with better sound insulation qualities than those of hard board, plywood, asbestos cement flat sheets etc., This material is now known as 'kohutex' from the Sinhala word 'Kohubath' for coconut fibre waste. When higher strengths are required, the solution has been to reinforce the kohutex sheet with a pre-pressed fibre mat set in rubber latex.

The use of coconut fibre in conjunction with certain mineral binders has produced a beautiful ceiling tile with a very high surface finish at a fraction of the cost of imported ceiling tiles. Needless to say that the raw material is entirely indigenous.

The most important industrial raw material produced in this country is rubber, and there is a large potential in this material for use in industrial products and equipment, where imported materials have to be used, in addition to the manufacture of traditional products like motor car tyres, conveyor belts, pressure hose etc., which can be produced in Ceylon.

One main area where rubber can be used to replace imported traditional material is in the manufacture of pumps especially those subject to heavy abrasive wear or chemical attack. The normal method of attack had been to use rubber as a lining to conventional casings, but the lower price of rubber in Ceylon enabled us to make the pumps in rubber with a lighter casing on the outside. This got rid of the problem of making the rubber lining adhere to the metal casing as the thickness of rubber did not require this adhesion. Very successful results have been achieved in the use of rubber in pumps, the most spectacular being their use in sand pumps used in suction dredging.

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We had the case where manganese steel pump volutes wore off with one week's operation handling the abrasive sand in the Kelani Ganga at Peliyagoda, requiring the expenditure of nearly Rs. 10,000 (major part of it in foreign exchange) for rebuilding the worn out casing. The rubber volutes costing less than Rs. 2,000/- gave a life of 6 weeks, with a rebuilding cost of about Rs. 200/- Sewage pumps have also been built of rubber to replace at much lower cost, those that were imported for the various sewage schemes. The life of the pump in rubber is much superior to the metal one in view of the greater resistance the former has to bacterial and chemical attack.

Further R & D in the application of rubber to pumping problems enabled the successful production of a submersible peristaltic pump where the motor and other moving parts can be isolated from the pumped liquid without the use of the usual shaft seals which are a source of constant trouble. It can be used for tube wells as well as for de-watering excavations with a lot of grib and mud.

There is no harm in repeating that the potential of rubber in industry is very great indeed, and that it is a fruitful field for R & D.

Machinery Development

The development and manufacture of machinery and equipment for agriculture and the various industries can absorb a large amount of R & D work especially at a time when expansion of agriculture and industry is so dependent on import of machinery and equipment. While it is not suggested that everything that we require should be made here there are areas in which our scientists and technologists can make a significant contribution in this field. Our people can acquire skills rapidly and this can be used for our benefit if the necessary leadership is given in a convincing manner.

Our own R & D was directed towards the building of heavy equipment like dredgers, pumps and fans for special applications etc., and development of more basic things like components for hydrostatic transmission of power like hydrostatic pumps motors, valves etc., In these developments the available manufacturing techniques were always in mind, and the design of the products adjusted accordingly.

One important development was the use of hydraulic turbines for driving the auxiliaries of a suction dredger. It has been our experience that under conditions prevalent in Ceylon, D.C. drives or hydrostatic drives are not very suitable for this purpose due to various reasons. The faults that come up in a D.C. system under the damp and dirty conditions that can occur in a suction dredger can cause frequent delays. Similarly the hydrostatic system can also give trouble due to dirt and also lead to expensive losses of hydraulic oil in the case of an accidental leak. However, the hydrostatic system is superior to and cheaper than a D.C. system.

The solution to this problem was the use of turbines to drive the various winches, the water under pressure required to run them being supplied by diesel driven pumps using the water in which the dredger is operated. The turbines and pumps were developed and built by us and the system has proved to be quite successful.

One development which has very high potential in Ceylon is the use of concrete for machine tools. A considerable amount of work has been done in the Soviet Union on this subject and these results have been the starting point of our own work. The parts of a machine which are normally massive castings or heavy steel fabrications can be replaced with concrete, generally prestressed. This has found useful application in heavy hydraulic presses of over 100 ton capacity, where the costs have been less than half that of presses built in cast iron or fabricated steel. This has also got over the problems of machining heavy castings or steel fabrications. The R & D work on 'kohutex' and laminated timber products would not have been practicable for us if not for this development. Concrete has also been used in the construction of a hydraulic morticing machine and in the construction of an electric overhead travelling crane.

Development work in mechanical engineering had been handicapped by the difficulties in obtaining components for hydrostatic systems and this has spurred on R & D in this field resulting in some quite novel components. A cam-roter type of pump/motor has been developed with a steel ball in place of the usual vane in this class of pump/motor. The same principle has been extended to water pumps and air compressors. Further work is being pursued in this field.

Certain weak features in spool type hydraulic valves have been investigated and solutions found. It is well known that there is no way of reconditioning worn out spool valves without replacement of the sleeve or body or the spool. A valve has been developed using a flat slide to replace the spool resulting in easier manufacture and convenience in maintenance.

A very interesting development is the compact reduction gear using steel balls. This gear can be used for very high ratios. It is very compact compared to other gears giving such ratios and has the in-put and out-put shafts co-axial.

Work on air bearings for high speed applications and hydrostatic bearings for heavy loads is in progress. A high frequency motor running at 15,000 rpm running on a air bearing has been developed for spinning spindles used for spinning cotton.

A machine for casting hollow floor slabs on the long line of prestressing has been developed making use of the inflatable rubber tube with longitudinal reinforcement which was developed for forming ducts for prestressing cables without the usual wobble which has been a feature of ducts formed by inflatable rubber tubes available so far. The rubber tube is made in such a way that it can expand in diameter but it can be kept straight longitudinally with provisions for taking the longitudinal curvatures necessary for curved prestressing cables.

In the field of electrical engineering developments have been made in the construction of linear induction motors, which have been applied successfully to conveyors overhead travelling cranes etc. Application to passenger lifts is under development.

Electronic and Fluidics

There are many applications of electronics specially in industry where R & D effort is rewarding. The design and construction of controls for various industrial processes and in metrology has been given importance in our R & D work. An instrument for measuring the percentage of solids in the discharge line of a suction dredger has been successfully developed and applied to our own dredger. Electronic tachometers speed measuring devices for the traffic police, traffic signals, counters, load measuring devices etc. have been developed and are in use.

Fluidics is a recent development in control engineering and one possessing great potential for Ceylon. Most logic functions carried out by electronics can be carried out by fluidics at a slower speed. The speed is, however, adequate for most industrial purposes.

The important aspect is that fluidic elements can be manufactured by us as the manufacturing techniques are not as sophisticated or involving as much capital outlay as for electronic components. While it is unlikely that components for solid state devices will be manufactured in Ceylon in the near future, fluidic devices have already been made and used by us in some control work. These are also more robust and more reliable than electronic devices.

We are therefore concentrating on the development of fluidic devices and applications and the results achieved so far are very encouraging. The first logic unit to be made was a 4 input 'NOR' unit of the planer turbulance amplifier type. The first application has been the control of a pneumatic tile cutter with fluidic control for extrusion of the long span clay tile, manufactured at Anuradhapura. I see a bright future in this field of development. Applications in control of machine tools and in metrology are under development.

Conclusions

Ceylon has a good future in the field of light industry due to her potential of skills. This can be mobilised only by intensive R & D in applied science especially in areas where expensive facilities are not required.

I have dealt with the subject of engineering R & D in Ceylon in relation to these aspects where I have been directly involved and where I have been fortunate enough to have been able to make a contribution.

I wish to express my sincere thanks and gratitude to my colleagues in the State Engineering Corporation especially in the R & D and Mechanical & Electrical Engineering sections, and the staff of the Mechanical Section of the Colombo Port Commission. Their skills and co-operation have contributed in large measure to the success of most of the projects dealt with by me.

LECTURE BY CHIEF GUEST

CEMENT AND CONCRETE RESEARCH IN FUTURE URBAN DEVELOPMENT

by

G. M. IDORN*

Introduction

In presenting this lecture about *Cement and Concrete Research in Future Urban Development* it seems appropriate to mention its background.

The Concrete Research Laboratory Karlstrup, Denmark was established in 1960 by the Danish Cement Manufacturing Company: Aktieselskabet Aalborg Portland-Cement-Fabrik, running about 80% of the Danish cement production, i.e. about 2 million tons of cement in 1970. The research is only to a minor extent concerned with the problems of the manufacture of the product-cement-made by the sponsoring industry. So far, it has been more orientated towards the use of the cement, that is to say: the problems in manufacturing concrete.

So much of concrete manufacturing to-day in Denmark is industrialized that the research predominantly must concern industry problems, or in other words :

(i) process technology and

(ii) product development

rather than conventional design, making, and use of concrete.

Quite much of Danish know-how in industrialized concrete manufacturing is now being exported. Danish plants or licensed plants are to be found in Western Europe, Eastern Europe, Israel, USA, Thailand, and elsewhere. As it is well known, cement manufacturing industry is an important all over feature of Danish export.

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This outlook in Danish cement and concrete industry forces the concrete research to apply a global, rather than a national view on its function as a basis for innovation of cement and concrete industry.

If we now look upon modern manufacture of cement from the point of view of concrete research there are three areas of problems to be considered seriously with regard to the development in the years to come :

(1) The steadily increasing cement consumption in the global, social development, the corresponding trends in cement manufacture and the creation of concrete manufacturing industries.

(2) The advance of basic knowledge on cement, its minerals and their formation during manufacture and on the characteristics of unhydrated and hydrated cement and its adhesion to aggregate particles.

YEAR	CEMENT–PRODUCTION–DENMARK mill. tons	KGS CEM/CAPITA*I-A
1920	0.2	64
1950	0.7	159
1960	1.2	266
1968	2.0	425

FIG. 1.

(3) The application of basic knowledge so as to create innovation in the manufacture of cements, cement products, concrete and concrete products in a still widening spectrum of types.

The task

There is no need to present extensive documentation for the fundamental importance of the manufacture of cement in modern life of people all over the world. Figs. 1 and 2 are significant expressions of what the consumption of cement, predominantly in concrete, has meant for the creation of the 20th century.

Speaking from an industrial point of view, the market is prosperous also for the years to come. But in a broader sense we might say that it is prosperous in a frightening order of magnitude.

There is not yet the problem of available natural resources as with some other raw materials. Limestone and rocks with silica and alumina are still among the most widespread mineral raw materials in most regions of the world, and ways of producing artificial aggregates for concrete etc. are at hand where suitable natural sand and gravels or rocks for crushing are becoming scarce.

The main problem of the future is rather, how the production can keep up with the demand for cement and concrete for the concentrated urbanization now coming afore in our countries.

J. Van Ettinger, in his book *Towards A Habitable World*, (1), issued in 1960, says :

"....in order to ensure reasonable housing for everyone in the year 2000 it will be necessary to build 1000 million dwellings in the present century, *viz.* 1100 million (......) less 100 million (......).

YEAR	CEMENT-PRODUCTION-WORLD mill. tons
1920	32
1950	133
1960	315
1968	509

FIG. 2.

To attain in the year 2000 a world housing stock of 1100 million dwellings of reasonable quality, it will be necessary to build in the forty-two years available roughly 25 million dwellings per year. Seeing that it will take a few decennia to attain a production of this size, it will be clear that in the second half production will have to be considerably greater than 25 million dwellings per year. This is especially necessary, because in the period 2000-2050 production will also have to be considerably greater than 25 million dwellings per year and consequently a higher rate of production must be attained at the end of the present century. In view of the enormous arrears production must be increased as quickly as possible and for this reason the relative increase in production in the first part of the period has been assumed to be higher than in the second part."

Twelve years have passed since the publication of this estimation of the global habitation problem. Figs. 1 and 2 indicate that cement industries have been aware of these perspectives, whereas Fig. 3 indicates, how far we still are from meeting the needs. And recent information concerning population growth and its increasing social problems in some regions of the world definitely support the view that we are still far from such a level of dwelling production that we are dealing with a systematic, controlled move "*towards a habitable world*".

On the contrary, the Danish delegation at a world conference held in November 1969 in Bruxelles concerning big city developments presented a survey of the difficulties involved in the urbanization of the Copenhagen area aiming at 2.6 million inhabitants in the

Output of Dwelling Units per 1000 Inhabitants	1960	1968
Austria		6.8
Belgium		5.1
Czekoslovakia		6.1
Denmark		9.2
Finland	7.1	
France	7.0	8.2
Greece		12.8
Hungary		6.5
Luxembourg		3.3
Malta		6.9
Netherlands	7.4	
Norway	7.4	
Poland		5.9
Romania	7.3	5.8
Spain		7.7
Sweden	9.1	13.4
Switzerland	9.3	
USA	7.1	
USSR	14.0	9.4
U.K		7.7
W. Germany	10.3	9.0
Many developing countries	2.0 or less	

FIG. 3. From : UN Economic & Social Council, E/C 6/12.9.12.1963 Annual, Bulletin of Housing and Building Statistics for Europe, 1968 United Nations, Economic Commission for Europe, New York 1969.

year 2000. An East Asian delegate opposed to calling this difficult, referring to the fact that the capital of his country now holds about 10 million inhabitants without having any noticeable modern facilities, and it is expected to have 30 million inhabitants in 1990. There are no plans laid out for urbanization and no capital available for such investments.

The importance of cement and concrete for housing and construction works to meet demands of this dimension is evident. And even the most powerful thinkable development of competitive materials must be considered helpful rather than a threat to the knowledge and trades involved.

This must tell everybody engaged in cement and concrete research that the actual production and technology in building and construction practice have an urgent need for support, not to ensure its survival as a field of trade or business, but to attain significant improvements of productivity as well as improvements of product qualities so as to make the necessary growth possible of the capacity of the building industries.

Advance of basic knowledge

In 1964 the American scientist Michael Michaelis said in an article in "International Science and Technology":

"*The principal issue is our attitude towards science and technology. If we can evolve a system approach to the utilization of science and technology, I believe we will create an environment in which science and technology can become an integral part of the mainstream of life.*"

In 1969 the ever increasing investments in science as a basis for new technology opened up for the conquest of space. With the above mentioned demands for habitation it seems appropriate to ask whether within the cement and concrete field we have created environments in which science and technology are becoming "integral parts of the mainstream of life".

Fig. 4, shows a prestressed concrete experimental road recently constructed by the Indian Road Research Institute as part of the highway connecting Delhi and Agra. The people of the immensely crowded farm country around are still living mostly as they have done through the centuries.

At the passage of this some twenty miles long pavement the visitor's first impression inevitably is : this is an extreme anomaly, advanced, experimental civil engineering cut through an enormous area of immobile stone age village life.

However, at closer consideration, one is tempted to accept this road as a heroic challenge to the environment, a daring symbol that India will firmly attempt to integrate science and technology in its future life and development. If this has been the attitude deciding the construction, we must look upon it with admiration not least, because while driving there it is easy to imagine an antagonistic reaction from the environment which could quickly pour the statics of the rural life back over the road and make it quite obsolete.

One might think that science, research and technology more strongly are influencing the main concepts of modern life in the industrialized regions of the world than in India. But this is not necessarily true.

In recent years big companies operating in the consumption markets in USA have introduced the " systematic value analysis technique ". Ad hoc expert groups are established, when a customer has a demand which cannot be met by existing products. Potential solutions are then formulated through penetrating discussions down to unambiguous definitions of the basic functions to be fulfilled, and thereafter by creative team-work in searching new ideas and technology. A special Society of Value Engineers already exists, and spectacular cases are known with big savings in costs of production and in creation of new products by utilizing this approach.

Admittedly, programming of science and research could be much improved by systematic expert group's brain storming. The alarming feature in value analysis as a tool in big business ' development work rather is that science is applied in a quite haphazard way and levelled in with occasional and lexical knowledge in the decisive process.

There is but little reason to cry for the freedom of academic, basic science in that romantic sense of this concept which inevitably now belongs to the pre-electronic era. What must concern us is that science and technology ought to evolve a system approach to the utilization of new ideas and concepts, and not accept merely to be used as a heap of occasional information.

It seems convincingly demonstrated that value analysis can be a powerful tool, probably not least because it incorporates the creation of a favourable environment for multiplication-effects by integrating individual resources. But science-research-technology could long ago have created environments of equal or superior power, instead of so often having accepted to live with, or vainly tried to break down–if not built–insurmountable barriers of terminology and ideology between research and practice. To change this tide we must understand the problem and its order of magnitude.

Fig. 5 is a compilation of the number of Research and Development, (R & D) employees against the totals of employees in 26 European industry companies, covering research intensive as well as research extensive fields of business. Representatives of these firms attended a conference in Denmark on R & D problems in 1969 and offered the information here presented. The figure seems to say that research-intensive industry (for instance pharmaceuticals) tends to employ 1 or more R & D man per each 10 employees for companies of say 1000 to 10,000 employees. This proportion falls off in the giant companies (oil, beer, electronics etc.) and the validity of a proportion is obscure in companies with less than 1000 employees.

Cement industry in general has much less R & D employees than 1 per 10, also outside Europe and with a few dynamic companies as the exceptions.

Fig. 6, from (2), shows the percentage of basic research expenditure to total research expenditure against total research expenditure (US = 1000) in a number of countries, big as well as smaller ones. In a number of the small countries a large proportion of the total research is basic–this will generally be synonymous with university and technical university research and work at public research institutes. At the same time the small countries have only few big companies, which are prepared to employ scientists or for that sake to apply and utilize science as basis for R & D activities.

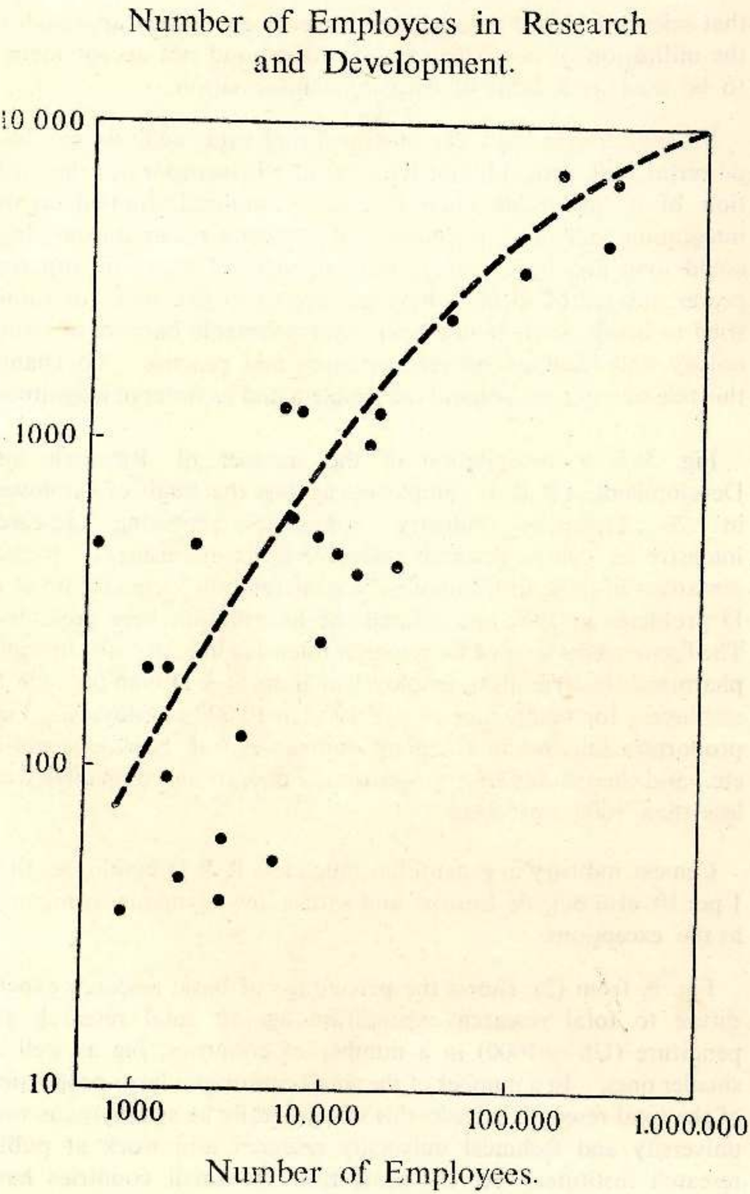

Fig. 5. Number of employees in Research and Development against the totals of employees in 26 European industry companies.

Cement chemistry as a part of silicate chemistry has played an important and spectacular part of university research, both in smaller and bigger countries for the last 150 years.

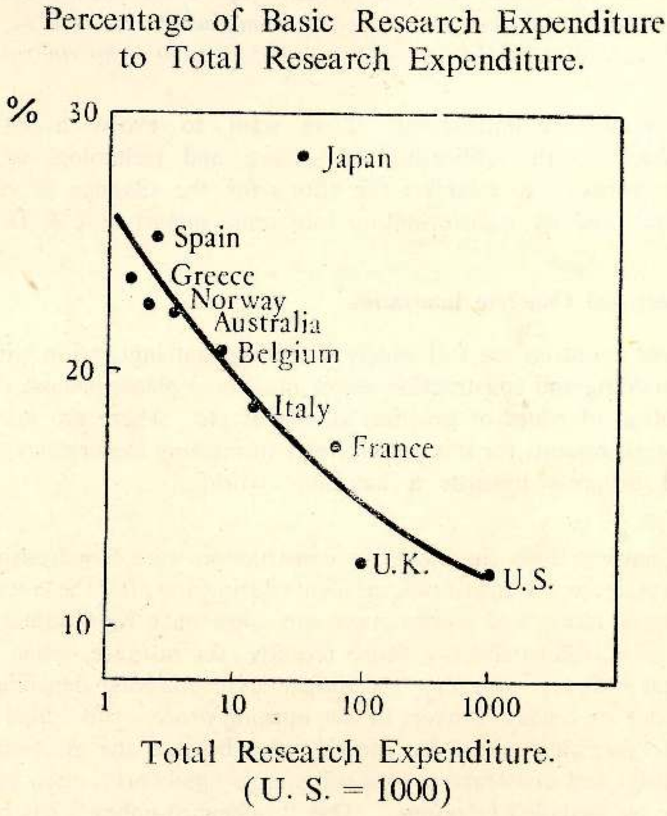

FIG. 6. Percentage basic research expenditure to total research expenditure against total research expenditure in some countries. From (2).

Cement industry has nowhere, except as minor fields of secondary investments, developed into the modern type of giant corporations (oil, steel, chemicals, electronics etc.) and comprises a good many quite small companies (less than 1000 employees). The cement industry does not belong to the research-intensive group of industry, and concrete manufacture is even much less a field of concentrated industry organization.

Thus, this is our picture : *A high proportion of the basic research is public and academic and only remotely related to its application in the R & D of cement and concrete manufacture. Cement manufacture is much less research-intensive than most other fields of modern mass production. Concrete manufacture is still in the larger part of the world only in an incipient phase of industrialization.*

This must be understood, if we want to evolve a system approach to the utilization of science and technology or, in other words : to reinforce the efforts for the advance of basic research and its transformation into more intensive R & D.

Cement and Concrete Innovation

Most countries are still widely accepting that innovation within the building and construction sector must take place through slow evolution of codes of practice, standards etc. There are mainly historical reasons for this peculiar way of meeting the urgency of a rapid progress towards a habitable world.

In ancient times the modes of construction were based entirely on experience. Catastrophic accidents during and after the erection of big buildings and constructions etc. must have been numerous and of shocking effects. More recently, for instance, when the cement industry grew up, the difficulties in attaining dependable qualities of cement clinkers in the burning process still called for public suspicion and strict control, also because the erection of buildings and construction was still simple handwork, often to be made by unskilled labourers. This " safeguard-policy " has been of heavy impact on research from far back in ancient times up to to-day's international committee work on standard specifications etc.

Immense series of costly, empiric tests are still made despite the fact that they are only vaguely reflecting the true characteristic of building materials exposed to varying complex environmental factors. In its entity this system of traditional acceptance testing is becoming more and more a barrier of retardation against further industrialization, and this is coming in still sharper contrast to the

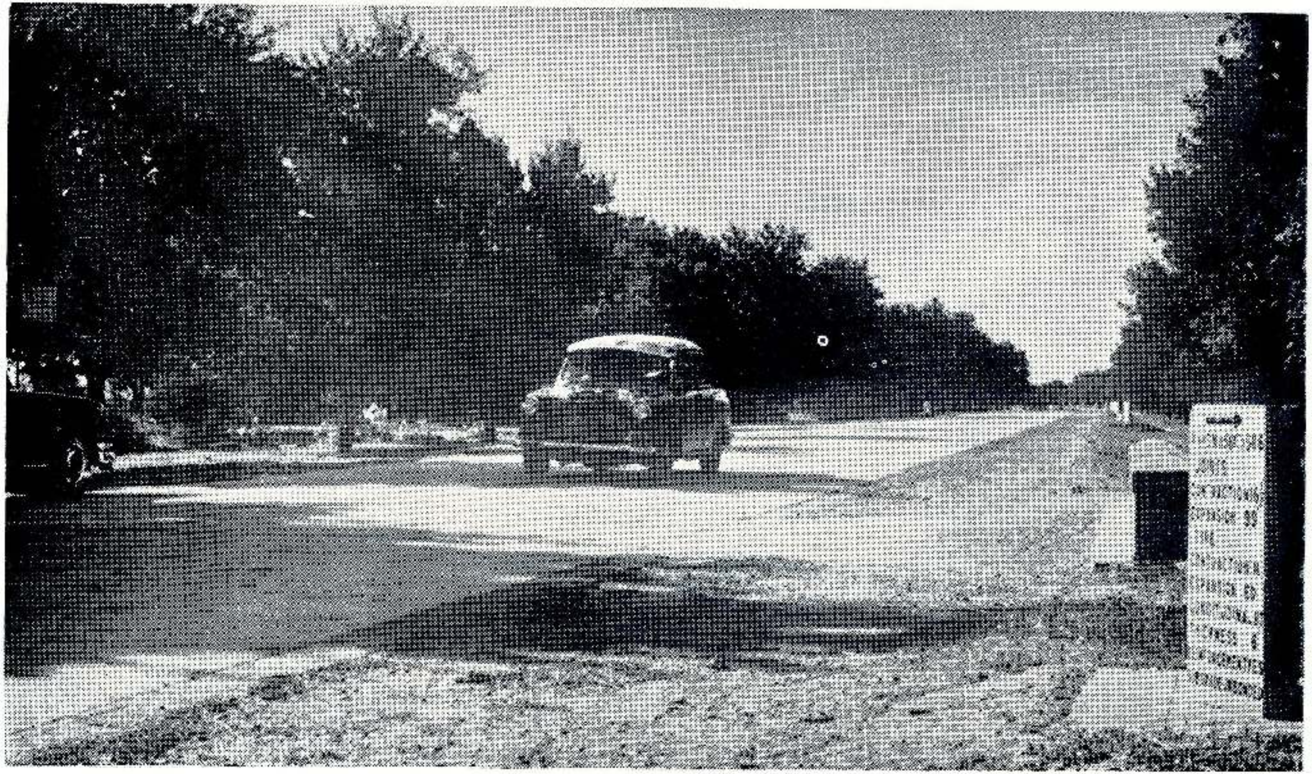

FIG 4. Experimental prestressed concrete road forming part of the highway connecting Delhi and Agra.

fact that theoretical research, modern instrumentation and datamatic expertise are available for a system approach to research and development and for control purposes, like already long ago introduced in other mass production industries.

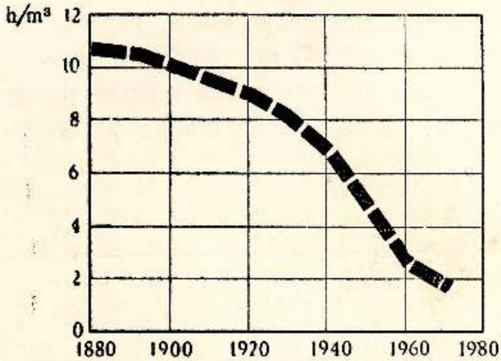

FIG. 7. Decrease in working hours on the building site per m³ dw volume in Sweden, 1880-1960. From (3).

It is also to a large extent due to the historic development that rationalization rather than qualitative innovation so far has been the predominant feature of the development of concrete industries.

Fig. 7 shows the decrease in working hours on the building site per m³ dwelling volume 1880 to 1960 in Sweden (3). Precast concrete commenced to contribute to the reduction from 5 to $2\frac{1}{2}$ hour per m³ in the decade 1950 to 1960. The predominance of rationalization rather than product innovation is also characteristic of the cement industry, especially for the last 20 years and particularly due to :

1. Mechanization of excavation and transport of raw materials.
2. Increase of kiln sizes (500 → 4000 ts/day).
3. Rationalization of kiln operation.
4. Introduction of bulk cement transportation.

The time has come to make the statement that the economic savings in these processes since the second world war exert but little influence on science and technology,

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Fig. 8 shows an indealized sketch of the innovation process in advanced industry. The "idea-model" phase (the research) constitutes the introduction phase and often less than 10% of the total costs of the R & D investment. The further work until the marketing phase is well established as a smooth, integrated and well controlled process, fitting into the larger scheme of industrial and commercial activity. An entire product development will often last five years or less in quite a few types of industry.

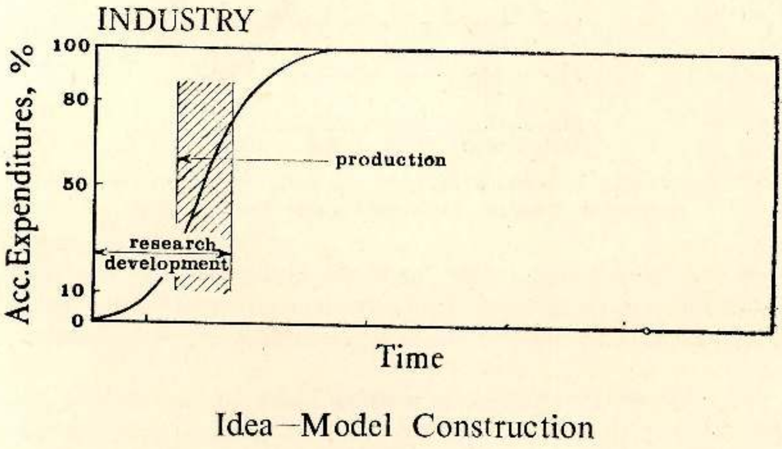

FIG. 8. Innovation process in advanced industry.

Fig. 9 represents an attempt to visualize the R & D feature of the building industry, in this connection considered the alias of either cement or concrete industry. Most research, basic as well as practically aimed, is institutional and ends up in publications, lectures etc.—and in a gap of communication with regard to application. However, some consultants, site-engineers, plant operators, plant constructors etc. will always try to find new ways and to pick up news from the literature, personal contacts etc. In the course of time new design, new materials, improved characteristics of materials etc. are thus brought forward.

Then comes the next gap, because the authorities depend on experience and demand time to be convinced of the security in accepting new things.

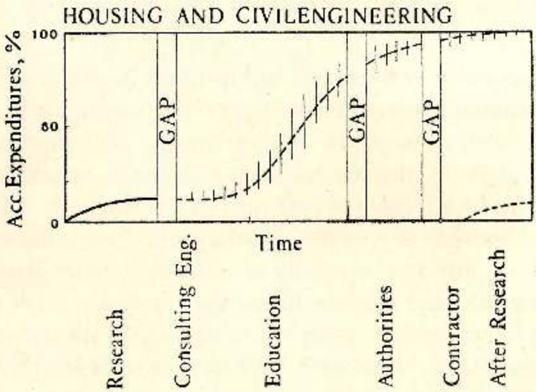

FIG. 9. Innovation process in the building industry.

Hereafter comes the third gap, because contractors, site engineers, plant operators etc. must be brought to understand and accept the new ideas and procedures. By now the accumulated costs of R & D have attained about 100%, and very often 20 years have passed before the break-through of a cement or concrete innovation, which commenced as an idea in a research institute, is put into practice.

Then at last comes often some failures, and this is the endangering barrier against a more rapid development towards a habitable world—now research is called upon to assist in trouble shooting, to correct procedures of manufacturing or to adjust products, into which basic misconcepts may well be built-in. In fact, in numerous cases such work is what people in practice have learned to understand by the designation research, and they have been taught so much from the way many research institutes have worked.

Research - Anvil or Hammer

The introduction during the forties of physico-chemical theory and experimental technique in concrete research in many respects replaced the traditional testing methods.

Thereby more meaningful and deeper acknowledgement of the nature of cement paste and concrete have been attained. But this has not resulted in powerful innovation of concrete manufacturing methods or in significantly improved characteristics of concrete products, e.g. workability, strength, durability etc.

The precast concrete industry for instance is still largely based upon conventional concrete technology. The savings and capacity increase has been attained by mechanization and rationalization. Even acceleration of the hardening for instance by steam curing has been introduced quite empirically, and research has merely been utilized sporadically in this development for trouble shooting and for testing purposes, resulting in not much more than adjustments of materials and manufacturing specifications. *For labourers and civil engineers precast concrete is still largely concrete as it was on the building site in the old ages.* Thus, the creation of the precast industry is due to the machinery industry, and to the engineers of design and construction.

Fig. 10 shows houses of concrete, cast on the site, in the famous English Welwyn Garden City, erected in 1928-1932, about 30 miles north of London, and still a beautiful, habitable town. Fig 11 shows a Danish urban development, erected near Copenhagen in 1969-1970. The concrete here has been manufactured entirely in factories as standard beams, columns, decks and walls according to a sophisticated design, manufacturing and erection system, often designated : "system-building". But the concrete is in all important characteristics still the same material as in the Welwyn Garden City work, which was made by much more primitive means forty years ago.

Much research is now going on to develop concrete as a material. Powerful new techniques like micro-calorimetry, scanning electron microscopy etc. are put in action, but in the opinion of the writer we—the concrete research institute people—are still working far too much piece-meal, and with insufficiently clear technological aims of our work. This is delaying the possible innovation as compared with what could probably be achieved by forming strong temporary project groups making continuous flows of information from basic and applied research to the industry's R & D work.

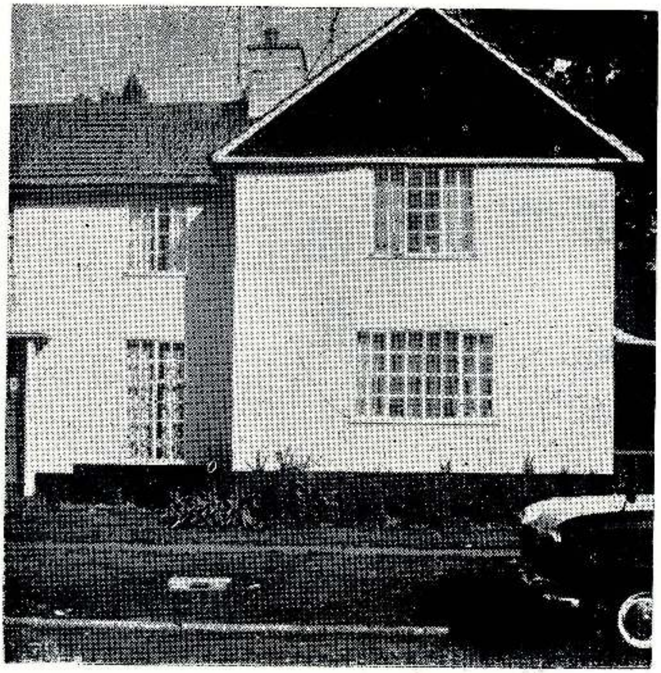

Fig. 10.

FIG. 11.

Efficient organization of R & D activity is well established in other fields of industry, and may well be forced upon the cement and concrete industry before long. This is because savings in the costs of materials in concrete commence to be attractive. This leads towards more efficient utilization of the cement, e.g. attempt to reduce the cement contents of concrete. This again brings the homogeneity and the level of the characteristics of cement more into the focus than when conventional technique is used. At the same time cement industry is in a phase of remarkable rationalization, particularly with regard to sizes and capacities of rotary kilns. And it is not easy simultaneously to reduce the quality variations to much less than has always been quite acceptable to concrete manufacturers. Thus, the probability must be expected to increase in the years to come for failures in precast concrete manufacture, if research does not very soon mobilize considerable efforts in solving the most pertinent problems *before* failures necessitate painful and defensive investigations involving loss of prestige, controversies with authorities and retardation of further innovation and growth.

Fig. 12 is a compilation of some major fields of operation under problems for the concrete industry of to-day and tomorrow. The industry must have these things under control, technologically and economically, instead of being left to continuous trial and error of short-sighted trouble shooting. The problem outlined in Fig. 12 may be transformed in the following framework of important areas of research :

Cement Mineralogy. X-ray optical and electronic microscopy, DTA etc. together with data processing will soon make it possible to produce and interpret at high rates unlimited amounts of data on mineral compositions of cement, clinker mineral textures, impurities etc. The influence of these factors on the properties of cement paste and concrete can then be attacked with great power. This research is of equal importance for the cement manufacture development.

Powder Technology. Basic physico-chemical knowledge on the nature and behaviour of powdery materials have so far not been widely applied in precast concrete technology. Hence, coming fields of intensive studies must be : cement fineness and cement granulometry, and also more general studies of the nature and behaviour of finely ground powdery materials. Also cement manufacture is urgently needing studies of these subjects.

Paste Physics and Chemistry. The nature of fresh cement paste and its behaviour under vibration, transport etc. can now, by applying basic science and electronic experimental technique be dealt with in meaningful quantitative measures. Precast concrete innovation has an urgent need for this research, for instance to the optimizing of mix compositions, improvement of compaction, control of setting etc. Cement industry has interests in this knowledge with regard to slurry problems and false set phenomena etc.

Structure and Strength. Description of the hydration process, the structure formation and the nature of strength and of rupture in hardened concrete is now being approached by basic science supported by powerful, modern instrumentation and datamatics. This knowledge must be applied in studies with the aim to accelerate hydration, improve strength levels, control industrial manufacture processes and final products. The cement manufacture has much interest in the correlation of these studies with more accurate knowledge on cement characteristics etc.

Durability. Time has come to remove the research on durability from the civil-engineering acceptance testing methodology and to apply science on ion-migration, rupture mechanics etc., aided by modern physico-chemical instrumentation. New regions for habitation may well create unpleasant surprises with regard to deterioration problems. Important problems exist concerning de-icing deterioration, aggressivity of contaminated waters, alkali-aggregate reactivity and long-time effects of initial, plastic shrinkage.

Concluding Remarks

The intention of this paper has been to present some ideas and motivations for discussions going on in our country concerning cement and concrete research and R & D activity, both in cement industry and in the concrete industries.

We now find classical, post war ways of organizing institutional research with its heavy working procedures of cooperation and exchange obsolete, are not efficient as stimulation for the innovation

Water

Industrial waste waters and even sea water will have to be made acceptable as mixing water in regions where fresh water supplies for domestic purposes tend to be threatened.

Aggregates

Selected high-quality aggregates will be demanded for special concrete of high density and strength. Resources of conventionally acceptable aggregates are being emptied in some regions and must be replaced by :

1. Crushed rock types of a wide range of qualities
2. Artificial aggregates
3. Gravels, so far considered too contaminated

Mixing and Placing of Concrete

Automation and " flow " of manufacturing process will be aimed at by the mechanical and electronic industries involving:

mixing
transportation
placing
compaction
demoulding
registrations and controls

Structure Formation and Hardening of Concrete

Savings in labour costs and innovation of concrete properties as a structural material point towards the use of :

accelerated hydration by steam,
electricity and hot water curing

chemical accelerators

micro-structure reinforcements
(monomer/polymers)

FIG. 12.

of industry. I am convinced that the problem of 1970 is to facilitate flows of information so as to create operational entities of our knowledge on :

basic natural science
silicate chemistry
cement and concrete technology
cement manufacture
concrete manufacture
electronics and data processing.

Naturally, many aspects of this philosophy have not even been touched upon in the preceeding analyses despite the fact that we can see before us a rising wave of turbulent development both regarding the inherent problems of science and research and concerning the ways by which to make our achievements useful for technology and constructional enterprise. This is the basic challenge in the present situation.

And the problem of habitation to people belong to us in common, although there are degrees of differences with regard to actual technical levels, food consumption and so forth. This means that ways of improving the rate and efficiency of making concrete should be made available to all people.

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SECTION A—MEDICAL AND VETERINARY SCIENCES

Presidential Address*

WHY DO DRUGS ACT ?

by

S. R. KOTTEGODA.

It would amount to affectation if I were to deny my deep appreciation of the honour of being elected President of Section A of our Association. I see in the audience some of my learned predecessors in this office and I sincerely hope that my effort today will not diminish the high standard set by them.

If some of you are thinking to yourselves that I may have been a trifle rash in selecting " Why do drugs act?" as the title of my address, I must assure you that my thoughts, just now, run on similar lines. For, were I to be asked to give a straight reply to the rhetorical question implied in my title: " Do we know why most drugs act?", the answer would reveal a considerable degree of our ignorance in this field. There are, to my mind, two other questions associated with my title. These are: " Where do drugs act?" and " How do drugs act?" We know much more about answering the former question in the anatomical sense and much less about the latter.

Voltaire is reported to have remarked that medical treatment consisted of pouring drugs of which we knew nothing into a patient of whom we knew less (Dunlop, 1970). However, since this remark was made some 250 years ago, a reasonable amount of knowledge concerning drugs has accumulated. In the last 25 years or so, due to the combined efforts of the chemist and the biologist, attempts at ascertaining the mechanisms of actions of drugs have been rewarded with some measure of success ; I use the term biologist here in its widest sense.

*delivered on 16th December, 1970.

Drugs are medicines. William Osler once said that the chief characteristic which distinguishes man from other creatures is man's great desire to take medicine. This characteristic of man is very ancient, and carries with it the cumulative weight of superstition and magic, folklore and old wives' tales.

According to Cooley (1963) the oldest prescription available is a clay tablet in cuneiform writing imprinted by a Babylonian physician in about 2100 B.C. The prescription runs as follows :—

" Purify and pulverize the skin of a water snake, pour water over it and the amamashdubkashkal plant, the root of myrtle, pulverized alkali, barley, powdered fir resin, the skin of the kushippu bird. Boil ; let the mixture's water be poured off. Wash the ailing organ with water; rub tree oil on it; let shaki be added."

The amamashdubkashkal plant, the kushippu bird, and later ingredients like *infusion buchu* and *tincture viburnae prunifoliae*, have, with a host of others, disappeared into the grist mills of time and history. These items are no longer in those official compendia of drugs, the pharmacopoeias and the formularies. But not all such earlier preparations have been so discarded. Digitalis, which came to us from an old wives' tale and one of the oldest of drugs, opium, which contains morphine, occupy important places in modern therapeutics. It is a sobering thought, however, that while much is known concerning the actions of these two drugs, their fundamental mechanisms remain to be elucidated.

Those older remedies which have been discarded, suffered such a fate for several reasons. Among the important of these are :

1. lack of pharmacological action or ineffectiveness in the disease claimed to benefit from the remedies, or both.

2. replacement by less toxic or more reliable preparations.

With reference to the first reason, my colleague, Professor Bibile, in his Presidential Address to this Section has discussed the principles of the Controlled Clinical Trial. Very briefly, it is a system of assessment designed to ascertain whether a cure ascribed to a particular remedy is real and not due to chance (Bibile, 1959).

Our pharmacopoeias have not shrunk as a result of this weeding. This is because new drugs have come to occupy and flow over the places vacated. It has been observed that 90% of the prescriptions written today could not have been written 20 years ago because the drugs prescribed did not exist. These newer drugs, the bulk of which are synthetic chemicals, have been extensively studied. Some of them have replaced earlier ones of biological origin which were often of varying potency. For example, thyroxine and chloramphenicol used today are synthetic compounds whereas earlier these were obtained, somewhat tediously, from animal and vegetable sources respectively.

It cannot be denied that our medical forbears did not look for, speculate upon, the reasons for the beneficial effects they attributed to the remedies they used. Liverwort, for example, was believed to be of benefit in disease of the liver because of the resemblance of the leaf to that organ. Again, a favourable influence of the planets upon the effectiveness of a drug was not discounted. Chaucer, the English poet, who travelled widely in Europe, and whose writings contain much medical knowledge of that time, described the physician in *The Canterbury Tales* (Coghill, 1954) thus :

> "For being grounded in astronomy,
> He watched his patient's favourable star........
> He gave the man his medicine then and there."

Modern medicine has left such speculation and vagary behind and today much effort is directed towards ascertaining the mode of action of drugs. This, in my view, is one of the fundamental differences between modern medicine and other systems of medicine prevalent today. Before I enlarge a little on this observation, I feel it my duty to say a few words about the term "allopathy." This term is not infrequently used erroneously in our country as a synonym for modern medicine. It is regrettable that some of our own colleagues are not free from blame on this score; though the offenders, for the most part, are found among the practitioners of homoeopathic or of ayurvedic medicine.

Allopathy reached its peak in the 18th century. It was a system of treating disease and its effects by inducing different effects in the patient. The treatment was drastic. The underlying idea was that if the patient was sufficiently drained of blood by venesection, sufficiently made to vomit by emetics and sufficiently purged, then, as a result of these measures his symptoms diminished and he could be regarded as cured. Often the patient was almost dead (Burn, 1945).

Homoeopathy, in a way, originated as a reaction to allopathy. The homeopathic system was founded by Hahnemann who rightly ridiculed the idea that symptoms of disease could be relieved by producing other symptoms. His first principle was *similia similibus curentur :* "let likes be treated by likes". Hahnemann took a large dose of cinchona bark and was seized by a paroxysm perhaps due to severe gastric irritation caused by the active ingredient of cinchona, quinine. He thought that this paroxysm was identical with the malarial paroxysm he had suffered earlier. He explained that cinchona was effective in the malarial patient because it produced the symptoms of the disease in a healthy person. The second principle of Hahnemann was that the effectiveness of drugs was greatly enhanced ("potentiated") by dilution. The dilutions advocated were of a high order, e.g. 1 part in 10^{60}. A. J. Clark has cited evidence that this corresponds to about one molecule of the drug in a sphere with a circumference equal to the orbit of the planet Venus.

Ayurveda is, as you know, an ancient system of medicine which apparently embodies some cures but which has not, in spite of such claims, been subjected adequately to what we understand by scientific analysis. Some of its practitioners of today have expressed to me the view that the system is such that it cannot be subjected to such scientific scrutiny.

As far as I am aware, neither the remedies of Ayurveda nor those of Homoeopathy have been seriously submitted to assessment by the method of the Controlled Clinical Trial. With respect to Hahnemann's explanation of the effectiveness of quinine in malaria, for our part we are still uncertain about the mechanism of the action of the drug. Originally described as a protoplasmic poison, quinine has been shown to inhibit oxygen uptake and carbohydrate metabolism in plasmodia. It also has the property of inhibiting the sodium pump which is essential for maintaining the integrity of living cells. The antiprotozoal action of quinine is confined to some of the stages of the life cycle of plasmodia.

Another feature which distinguishes modern medicine from the other two systems discussed above, is that its theories are often modified and sometimes even abandoned when new data are available. This feature of modern medicine, strangely enough, is looked upon as a defect, especially by homoeopaths. In this context an observation by Dragstedt seems appropriate.

> " It is permissible to entertain a hypothesis but not to be entertained by it. When it has been proved untenable by facts, it must be discarded."

The word " drug " connotes different things to different people. To the patient or the dispensing chemist, it is a substance used in the treatment of disease. To the lay public, especially in the West, the word has unsavoury associations, e.g. drug takers, drug pedlars etc. To the pharmacologist, the term has the widest meaning; it is an agent capable of producing some alteration in the biological activity of living tissue. In such a context, drugs are used in clinical medicine as well as in the investigation of cellular activity or function. In the latter role, the drug becomes a pharmacological tool. For example, our knowledge of the autonomic nervous system stems largely from the investigations of Langley and Dickinson (1889) who used nicotine to map out connections of the autonomic nerves. Nicotine has been used in this manner even later (Kottegoda, 1953; Ginzel and Kottegoda, 1954). It must not be forgotten that in the situation where the physician administers a drug in the therapeutic test, the drug again assumes the role of an investigational tool.

The change in biological activity brought about by a drug is its pharmacological action. It is the ultimate consequence of physico-chemical interactions between the drug and functionally important areas in various living tissues. Pharmacologically active substances have been divided for convenience into two groups (Barlow, 1964 ; Gill, 1965).

1. Those compounds whose biological activity can be attributed to some physical property and not directly dependent on chemical structure.

2. Those compounds whose biological activity is dependent on their chemical structure.

Admittedly, this division is an over-simplification. Between these two extremes, there are drugs whose activity is due equally to their physical as to their chemical characteristics (Alstead, Macarthur and Thomson, 1969). Even a drug which acts exclusively because of its chemical configuration must possess some physical characteristic to enable it to gain access to the site on which it acts.

When we conceive of the pharmacological action of a drug we mean the total action of the substance. Most drugs have multiple actions in the body. With a particular drug in a particular therapeutic situation only one or two of these actions will be of use. These actions form the pharmacological basis for the therapeutic use of the drug. Invariably, there are in addition, other actions of the drug in the organism. These actions are, of course, unnecessary. They may prove a nuisance to the patient or be actually harmful to him. These unwanted or adverse effects, which I shall refer to later, are outside those due to overdosage.

The simple division of pharmacologically active drugs into two groups can be reconciled with another type of division based on the effective relative dosage of drugs. Here, in one group are drugs, such as caffeine, which produce their effects only when given in amounts sufficient to form a monomolecular layer over the whole area of the cells on which they act. In contrast are the substances, such as acetylcholine, in the second group. These produce their characteristic pharmacological action when given in amounts which cannot possibly cover more than a fraction of the area of the cells on which they act. The picture of a drug producing its effects by an action over a large area of tissue is consistent with the idea that its action is primarily due to some physical process. The picture of a drug producing its action only at a very small part of the cell surface is consistent with the view that the drug, because of its chemical structure, interacts with some " active spots " on the cell surface to produce its characteristic pharmacological action (Barlow, 1964).

The hypothetical active spots on the cells with which the drug interacts to produce an effect are the receptors. The receptor idea, like some other concepts commonplace today, is not new. The earliest suggestion for the existence of such sites is believed to have been made by Paracelsus 500 years ago. In the early part of this century two lines of investigation strengthened the concept of the receptor. Paul Ehrlich, the father of modern chemotherapy, impressed both by the high specificity of antibody against antigen and the interaction between synthetic organic chemicals and parasitic protozoa, postulated " side chains " in the protoplasm of the cells with which such agents interacted. Langley (1906), the pioneer of neuropharmacology, when studying the effect of curare on skeletal muscle contraction, suggested that the substance acted on a specialized area of the muscle which he termed the " receptor substance ". The ideas of Ehrlich and Langley initiated new thinking in pharmacology. These investigators were guided by the principle that the explanation of a drug action lay not in vague " tonic " effects or poorly defined " poisonous " actions but rather in physicochemical interactions between drugs and definite sites (Goldstein, Aronow and Kalman, 1969). In the 1920's Clark extended the receptor concept and suggested that the combination between a drug and the cell surface obeyed the Law of Mass Action.

The response of a tissue to varying doses of a drug can be measured. This is the dose-response relationship. In graphic form this takes the shape of a hyperbola or a sigmoid curve. Several theories have been put forward to explain the dose-response relationship. The inadequacies of Clark's hypothesis were pointed out by Stephenson (1956). In 1961, Paton put forward the rate theory. According to this the rate at which the drug-receptor complexes are formed and broken determines the type as well as the time course of drug action. At the present time it is not possible to choose between the various theories (see review, van Rossum, 1968).

I propose to confine the rest of my address more or less to those drugs which act mainly by virtue of their chemical structure ; that is, those which act on receptors. In most instances of this category some information of the chemical configuration of the drug molecule is available. Gill (1965) has pointed out that what we do not know about the chemical configuration of drugs pales into insignificance when the ignorance concerning the structure of the receptors is considered.

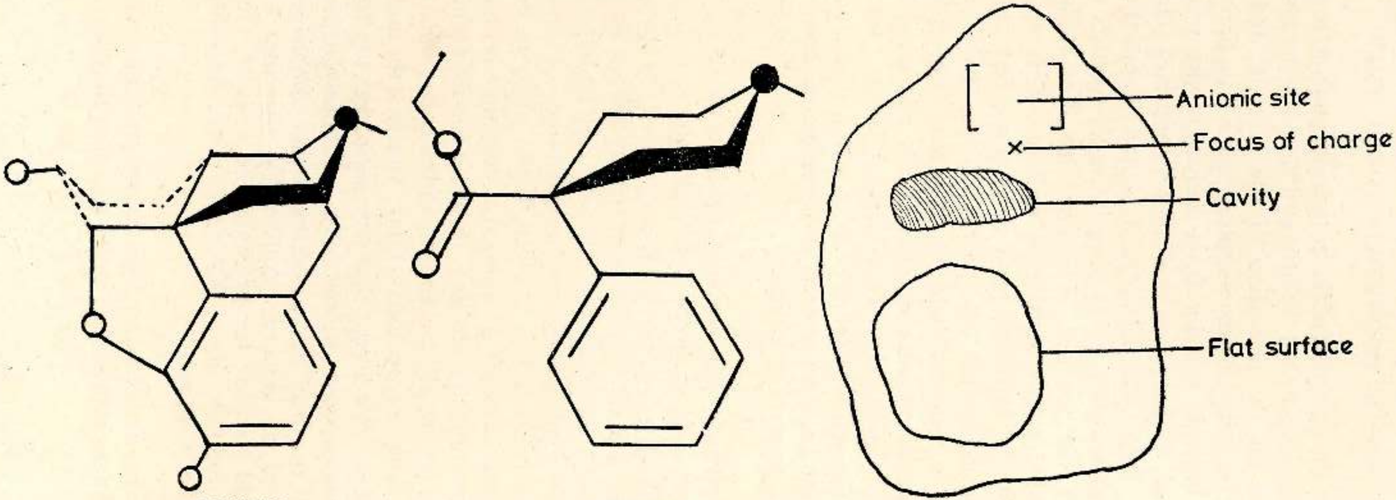
Receptors are assumed to possess a physical shape which is complementary to that of the drugs which react with them. On this premise the physical shape of some of the receptors has been imaginarily visualized. It follows that alterations in the chemical structure of a drug which reacts with a receptor will reduce the activity of the drug; drastic alterations will abolish the activity completely as the drug will cease to possess a shape complementary to that of the receptor. De Jong (1964) has described the receptor thus :

" To most modern pharmacologists the receptor is like a beautiful but remote lady. He has written her many a letter and quite often she answered the letters. From these answers the pharmacologist, has built himself an image of this fair lady. He cannot, however, truly claim to have seen her, although one day he may do so. "

The investigations of Beckett (1956) have given us a picture of the receptor on which morphine acts. Figure I (which is adapted from Beckett, 1956) illustrates the essential features of the morphine molecule which reacts with the receptor. It is seen that the synthetic analgesic, pethidine, also possesses the necessary configuration for combination with the receptor. We can answer the question " why do the analgesics, morphine and pethidine, act ?" by stating that they do so because they possess the necessary chemical structure for reacting with the receptor; we are still uncertain as to how this interaction produces analgesia.

Although receptors are usually imagined to be on the cell membrane it must not be forgotten that drugs may act intracellularly ; in this case the reaction might be with an intracellular enzyme which is the receptor. In fact, our ideas of receptors are patterned on those of the active centres of enzymes.

In order to produce a pharmacological effect a drug must have affinity for a receptor ; this affinity is due to the complementary " fit " between these two. When, after such an interaction, a cellular response is initiated, the drug is said to have " intrinsic activity " (Ariens, 1954) in addition, of course, to receptor affinity. On the other hand, a drug may have only affinity for the receptor; here the combination with the receptor does not initiate a response.



MORPHINE PETHIDINE

Fig. 1. The basic features of the morphine and pethidine molecules as well as the visualized receptor with which these react. (adapted from Beckett, 1956)

In such a situation the structure of the drug is adequate, so to speak, to combine with the receptor but the drug still lacks some additional structural features for the activation of the receptor and thus initiate response ; by occupying the receptor, such a drug prevents a drug possessing intrinsic activity from activating the receptor. Hence drugs which possess receptor affinity but lack intrinsic activity produce their pharmacological action indirectly. By occupation of receptors they act as competitive antagonists to the receptor activators, the agonists. The latter are often substances normally produced during physiological activity. A receptor of the type which can be activated by a drug possessing intrinsic activity is a " pharmacological " receptor (Gaddum, 1962). There is another kind of receptor with which a drug may interact but at these sites the interaction does not produce a pharmacological response directly or indirectly. This is the " silent " receptor (Collier, 1966). The combination of a drug with a silent receptor may result in the storage, binding, excretion or enzymatic conversion of the drug into inactive products.

For drugs to interact with receptors we have to assume that preformed receptors exist in the body for the variety of drugs we choose to introduce into it. Such an assumption is unnecessary if the possibility exists for the formation of new receptors when the organism is exposed to drugs. The difficulty that immunologists experienced in conceiving sufficient preformed antibodies for all the possible antigens is relevant here (Collier, 1966). The underlying theme of the current theories of antibody formation is that the antigen directly or indirectly acts as a template for the formation of new antibodies. After all, the antigen-antibody combination is no different to the drug receptor interaction. In effect, the antibody is a type of receptor. We accept that new antibodies are formed when antigens are introduced into the body. Similarly, depending on the structure of the drug, new receptors having complementary patterns are formed or induced. Apparently, this idea is not confined to medical science ; for example, the novelist, Graham Greene, (1951) introduces one of his books with the following quotation from Leon Bloy.

> " Man has places in his heart which do not yet exist, and into them enters suffering in order that they may have existence."

Clinically, certain drugs, the immunosuppresive agents, are used to prevent the formation of antibodies. These are used, for example, during organ transplant operations. Drugs capable of eliminating receptors already formed are known. Dibenamine, for example, inactivates receptors for adrenaline (Nickerson, 1949). Instances of drugs causing an increase in the number of receptors are also available. It has been shown that the catabolic activity of the liver which follows the administration of phenobarbitone or exposure to DDT (dicophane) is due to these agents causing an increase in the number of (non-specific) silent receptors. This phenomenon is called "enzyme induction". It results in the more rapid inactivation of phenobarbitone itself, when given subsequently, or of other substances. This property of DDT to increase the silent receptors has, in fact, been successfully used in the treatment of neonatal hyperbilirubinaemia. In this condition there is an accumulation of bilirubin in the blood due to an insufficiency of hepatic microsomal enzymes which normally conjugate bile for excretion. DDT induces the formation of the enzymes and relieves the condition (*Lancet*, 1969). Again, a common feature of analgesics such as morphine and pethidine is the appearrance of tolerance in the patient. Tolerance is the reduced response of the body to a drug when the same dose is administered over a period of weeks. This phenomenon has been explained (Collier, 1966) on the basis that such repeated exposure to these drugs causes a decrease in the pharmacological receptors (like that caused by immunosuppresive agents or dibenamine) or an increase in the number of silent receptors (such as is caused by phenobarbitone or DDT).

Before discussing some examples of drug-receptor interactions, I would like to illustrate the drug in the role of a pharmacological tool. In the instance I have chosen, two drugs have been used in this fashion. They are drugs in the widest sense i.e. in the pharmacological sense. Both are poisons. One is botulinum toxin. The poisonous effects of this are due to the selective and irreversible block of all cholinergic nerves in the body. The other drug, tetrodotoxin, is a poison obtained from a species of fish. The pharmacological action of this toxin is blockade of all autonomic nerves.

We know that the wall of the mammalian gut contains two layers of smooth muscle: circular and longitudinal. It is established that the excitatory nerves to the longitudinal muscle are cholinergic. It is generally assumed that the same applies to the excitatory nerves to the circular muscle. The experiment illustrated here is one of a series designed to test the validity of this assumption.

A piece of guinea pig-ileum was suitably maintained and the intramural nerve plexus, which supplies both layers of muscle, was stimulated electrically using different frequencies. The ileum was next exposed to botulinum toxin for 1 hr. Figure 2 shows that now stimulation failed to cause a contraction of the longitudinal muscle while the circular muscle responded. When the stimulation was repeated in the presence of tetrodotoxin, the response of the circular muscle was absent indicating that the earlier contraction was nerve-mediated. On the basis of the findings of this investigation the suggestion has been made that the view that the motor nerves to the circular muscle of the gut are cholinergic may need revision (Kottegoda, 1968, 1969, 1970a).

Peripheral Nerves.

The first examples I have chosen to illustrate drug-receptor interaction are from the cholinergic nerves of the autonomic nervous system. Activation of these nerves causes the release of acetylcholine at the nerve ending. This transmitter combines with the receptors on the effector tissues and initiates a chain of events which culminates in the appropriate response of the innervated tissue.

Two cholinergic sites which are often subjected to blockade by drugs used clinically are the neuromuscular junction in skeletal muscle and the ganglia of the autonomic nervous system. Neuromuscular blocking drugs are extensively used as adjuvants to general anaesthesia for the purpose of obtaining muscle relaxation and thus facilitate surgery. Ganglion-blocking drugs find use in the management of hypertension; by interrupting the vasomotor pathway to the blood vessels these drugs lower blood pressure.

The substance which activates both receptors physiologically is acetylcholine. Both blocking agents prevent this transmitter from combining with the respective receptors. The chemical structures

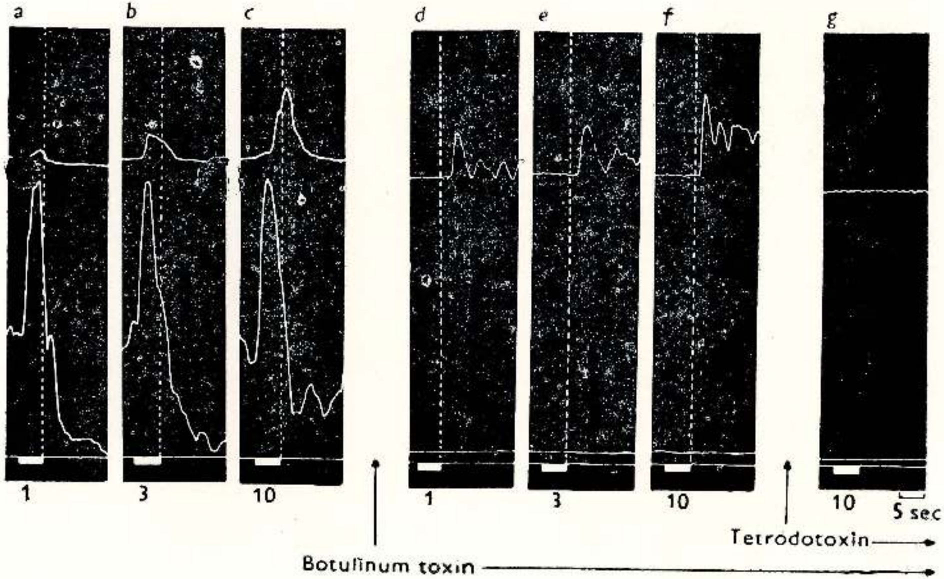


Fig. 2. Guinea-pig ileum. Upper tracing : contraction of circular muscle ; lower tracing : contraction of longitudinal muscle. (a-c) Responses to co axial stimulation at 1, 3 and 10/sec. (d-f) After exposure to 10^6 LD mouse units/ml Botulinum toxin, type D, for 1 hr, the longitudinal muscle contraction was abolished. (g) Tetrodotoxin 2×10^{-7} g/ml abolished the response of the circular muscle (after Kottegoda, 1969).

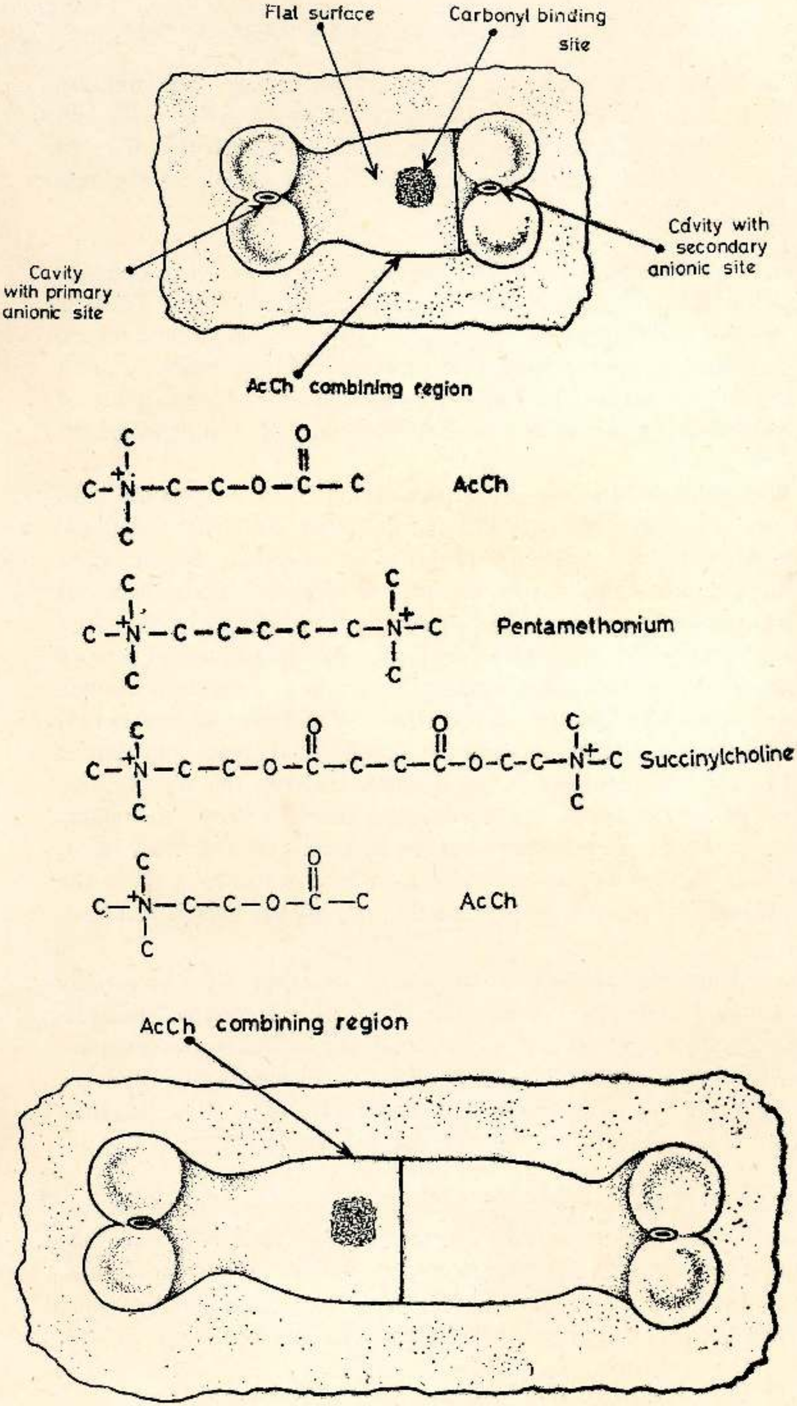


Fig. 3. Hypothetical acetylcholine receptors. At the top the ganglionic receptor at which pentamethonium acts as a competitive antagonist and at the bottom is the motor end plate receptor at which suxamethonium acts, (adapted from Goldstein *et al*, 1969). AcCh = acetylcholine

of the two respective blocking agents, though having some common features, are not identical. Figure 3 (modified from Goldstein *et al.*, 1969) indicates how it would be possible for these two drugs to bring about their respective pharmacological action at the two receptor sites.

It is seen that both receptors are visualized as having a configuration which is complementary to that of acetylcholine. There is an anionic site with which the cationic head of acetylcholine reacts. It has been suggested that a second anionic site exists in both receptors. Both anionic heads are recessed in cavities capable of accommodating two of the three CH_3 groups of acetylcholine.

The ganglion-blocking drug, pentolinium, has a structure sufficiently resembling acetylcholine to combine with the ganglionic receptor but lacks other characteristics necessary for the activation of the receptor. Thus, pentolinium has receptor affinity here but lacks intrinsic activity. By occupying the receptor, the drug prevents acetylcholine released during normal physiological activity from combining with and activating the receptor. The acetylcholine is soon inactivated by the normal route. The figure illustrates that the essential difference between the ganglionic receptor and that at the motor end plate lies in the distance between the two anionic sites, in each instance. In the muscle receptor these are widely placed. Hence pentolinium does not fit here. On the other hand, the muscle relaxant, suxamethonium, which is too long to fit the ganglionic receptor, is readily suited to occupy the muscle receptor.

Acetylcholine released at cholinergic receptor sites is rapidly hydrolysed and hence rendered inactive by the enzyme cholinesterase ; nerve activity is physiologically controlled in this manner. The configurations of acetylcholine and the cholinesterase (which is a receptor in this context) are complementary (Fig. 4). Suxamethonium is itself slowly hydrolysed by cholinesterase.

Next, I wish to discuss drugs which increase activity at cholinergic sites. Theoretically, this could be most readily achieved by administration of acetylcholine itself; but this method is not fruitful. Because of the ubiquitous nature of cholinesterase, acetylcholine introduced into the body will not gain access to the desired site as it would be inactivated *en route* by cholinesterase. For example, in man intravenous infusion of 60 mg of acetylcholine per minute produces only slight effects (Goodman and Gilman, 1965). On the other hand, if the enzyme cholinesterase is inhibited, acetylcholine which is continually released at the nerve endings, would accumulate. The drugs used to inhibit cholinesterase are the anticholinesterases, and of these neostigmine is one which is used clinically.

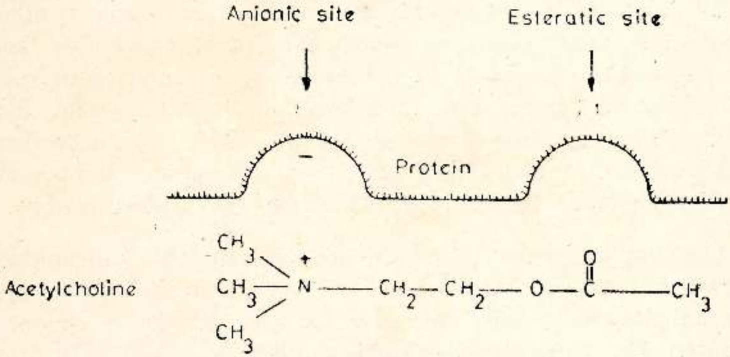


Fig. 4. Representation of the interaction between acetylcholine and acetylcholinesterase.

Neostigmine has a chemical structure sufficiently similar to acetylcholine to enable it to combine with cholinesterase (Fig. 5). Hence neostigmine "distracts" the enzyme from endogenous acetylcholine (Paton, 1955). The latter accumulates ; this increases

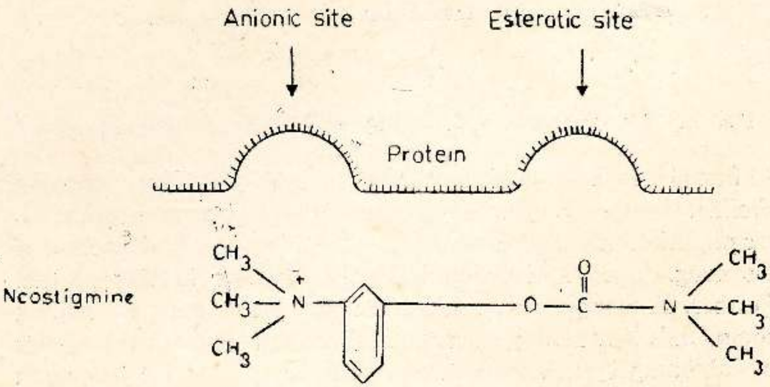


Fig. 5. Illustrates the interaction between neostigmine and cholinesterase.

cholinergic activity. This is why neostigmine acts. The drug itself is slowly hydrolysed by cholinesterase. Neostigmine is the cornerstone of the treatment of myasthenia gravis, a disease in which there is weakness of skeletal muscle.

It must be pointed out that, like Mary's little lamb, cholinesterase is found in the body wherever acetylcholine is released. Hence neostigmine would increase cholinergic activity at sites other than the neuromuscular junction. This action of neostigmine is an inevitable adverse effect of the drug and may occur at other cholinergic nerve endings. Further, since acetylcholine and cholinesterase also occur in the brain, neostigmine should, by inhibiting the enzyme, produce adverse effects in the brain. But when the drug is used clinically this does not occur. This is because, chemically, neostigmine is a quarternary ammonium compound; such compounds do not cross the blood-brain barrier readily.

Organophosphate compounds are also potent anticholinesterases but they differ from agents like neostigmine in several ways. Organophosphates react only with the esteratic site of cholinesterase. The reaction is non-specific and it is irreversible (Fig. 6).

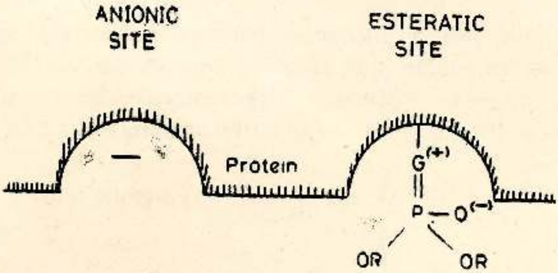


Fig. 6. The reaction between an organophosphate and cholinesterase.

At first glance they would appear to be ideal drugs for increasing cholinergic activity. However, since the action is irreversible, the physician will have no control over the duration of the action of the drug. Such a situation is rarely desirable in therapeutics. Further, since organophosphates are not quarternary ammonium compounds they readily enter the brain and produce adverse effects by inhibiting brain cholinesterase. In fact, one of the important contributory causes to death in poisoning with organophosphate insecticides such as parathion (" folidol ") is the high accumulation of acetylcholine these substances give rise to in the brain.

The physiological activity of the peripheral adrenergic nerves is responsible for a variety of functions. Among these are the constriction of blood vessels, control of the heart's action and relaxation of bronchial muscle. The adrenergic receptors mediating these effects are of two kinds (Ahlquist, 1948).

ADRENERGIC EFFECTS

α	β
Constriction of blood vessels, (skin, splanchnics)	Increase in rate of heart and its force of contraction,
Mydriasis	relaxation of bronchial smooth muscle,
	dilatation of muscle vessels.

Substances which react with these receptors and which possess intrinsic activity are the sympathomimetic amines ; these may be naturally occurring or synthetic. Noradrenaline, with minute amounts of adrenaline, constitutes the adrenergic transmitter. Isoprenaline is a synthetic amine which is a potent activator of some adrenergic receptors. The α and β adrenergic receptors, like the different cholinergic receptors, though similar in some ways, are different in other respects.

We know that the sympathomimetic drugs act because of their chemical structure, but the events which follow the reaction between them and the receptors is not anywhere as clear as those which occur at the cholinergic sites.

Isoprenaline is almost exclusively a β stimulant drug. Clinically, it is used for the relief of bronchial asthma. In this usage its disadvantage lies in the intense stimulation of the heart it produces; the heart also has β receptors hence the action there is inevitable. In fact, the increased fatalities in bronchial asthma noted in the last few years have been attributed to the indiscriminate use of isoprenaline inhalers (*Br. med. J.*, 1968). Recently, by slight modification of the structure of isoprenaline, a drug possessing almost exclusively relaxant action on bronchial β receptors was discovered. This is salbutamol (Cullum, Farmer, Jack and Levy, 1969). The stimulant action of this drug on the β receptors of the heart is minimal. From these and other observations it is now believed that the β receptors themselves are at least of two kinds (see Furchgott, 1967) β_1 (heart) and β_2 (bronchial). Fig. 7 shows the structures of isoprenaline and salbutamol.

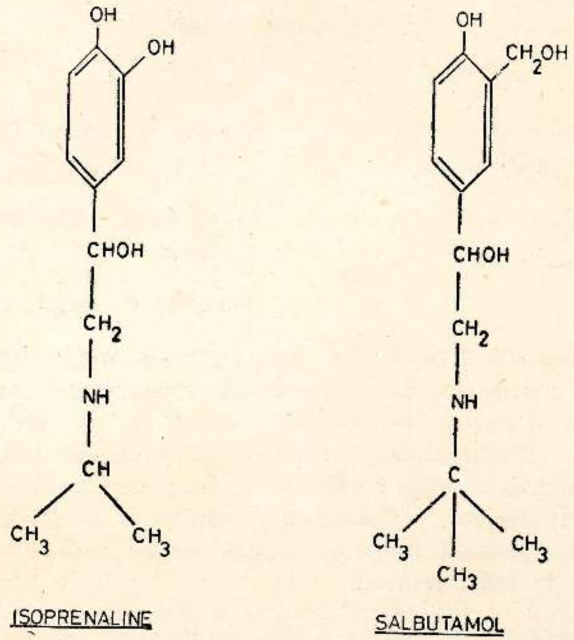


Fig. 7. Chemical structures of isoprenaline and salbutamol.

The cardiac stimulant action of isoprenaline itself is useful in conditions where the heart rate is slow e.g. heart block. In other situations it becomes necessary to interfere with the adrenergic activity on the heart when the latter's action is excessive as in tachycardia, or when it is desirable to prevent excessive stimulation of the heart as in angina pectoris. Since activation of receptors increases cardiac activity, a drug which blocks β receptor activity would be useful in the above conditions. One such drug is propranolol (Black, Crowther, Shanks, Smith and Dornhorst, 1964). Chemically, it is sufficiently similar to the β receptor stimulant isoprenaline to fit this receptor; propranolol merely occupies the receptors without having intrinsic activity. It prevents adrenergic activity influencing the heart.

Since β receptors are found in the lungs, propranolol may interfere with bronchial dilatation. This action is insignificant in non-asthmatics but the drug may precipitate an attack of bronchial asthma in those who are prone to the disease. This difficulty has been overcome by the introduction of practolol (Dunlop and Shanks, 1968) which acts mainly on the β receptors of the heart i.e. β_1 receptors. Since the drug has only weak actions on the β_2

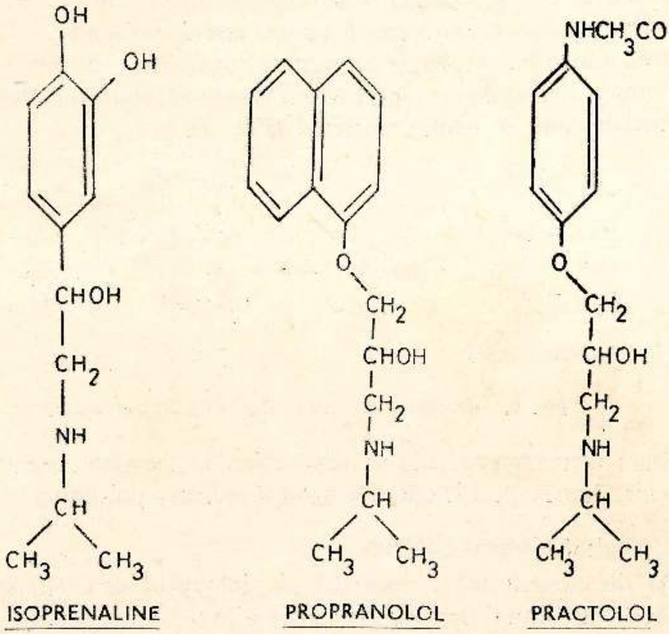
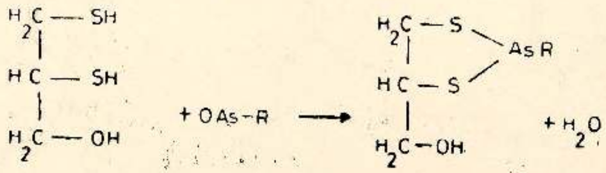


Fig. 8. Isoprenaline and the two β receptor blockers, propranolol and practolol.

receptors (bronchial muscle) it is safe for asthmatics. The chemical structures of the agonist at the receptors, isoprenaline, and the two competitive antagonists, propranolol and practolol are shown in Fig. 8.

Antidotes

Drugs may act by virtue of their chemical structure without the direct intervention of receptors. The best examples of this type of action are among the chelating agents. These can be used to remove toxic metals from the body. Here the interaction is between the chelating agent and the toxic metal which is in this context equivalent to the receptor. The simplest example is dimercaprol, British Anti-Lewisite (BAL). This compound was developed at Oxford as an antidote against the arsenical war gas, Lewisite. It was the first antidote to be synthesized on a rational basis. The poisonous effects of arsenic were known to be due to the substance combining with, and inactivating SH groups of certain enzymes of the body. SH containing naturally occurring substances were found to afford some protection against arsenic poisoning. Dimercaprol, which has available SH groups, combines with the arsenic forming a mercaptide complex which is soluble, stable i.e. does not dissociate, and is readily excreted (Fig. 9).



Dimercaprol

Fig. 9. Reaction of arsenoxide with dimercaprol.

Since mercury produces its toxic effect in the same manner as arsenic, dimercaprol is effective against mercury poisoning as well.

The Central Nervous System

At the present time, since the physiology of some important areas of the central nervous system remains to be elucidated, discussions of the mechanisms of drug action in this field are necessarily imprecise. Nevertheless, studies of the action of drugs on the brain have been rewarded with some clues to its physiology.

It has already been noted that acetylcholine, the peripheral cholinergic transmitter, as well as the enzymes concerned with its metabolism are present in the brain. Perhaps more fascinating is the finding that specific areas of the brain are rich in the adrenergic

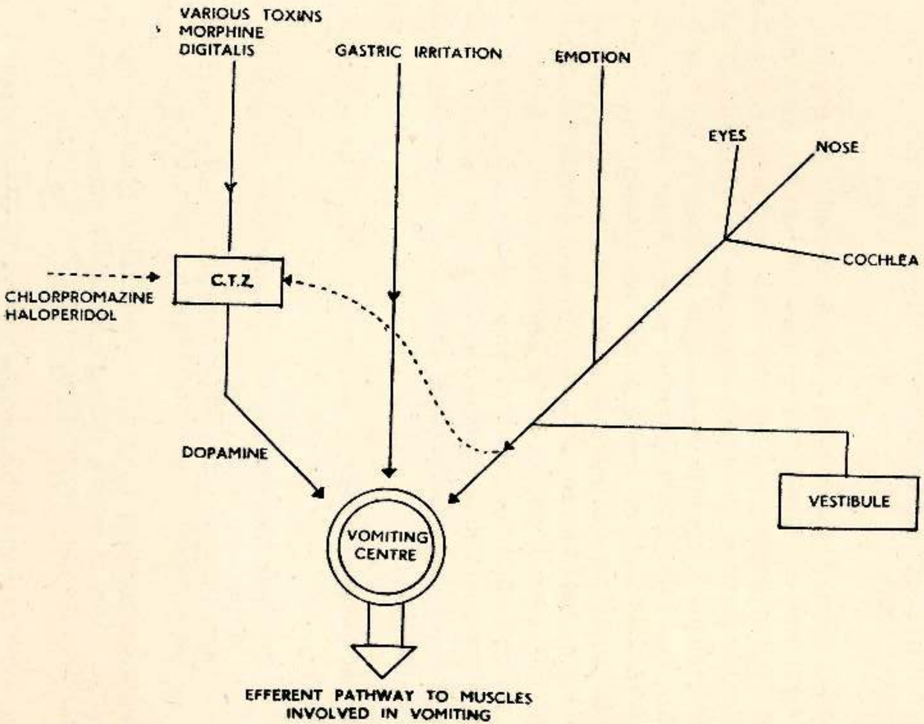


Fig. 10. Site of action of neuroleptic drugs in the afferent pathway of the vomiting centre.

transmitter, noradrenaline, and other amines such as dopamine and 5HT. These areas also contain the enzymes necessary for the synthesis and inactivation of these amines. In the peripheral nerves, the role assigned to dopamine is merely that of the precursor of nordrenaline and adrenaline. In the brain, it is increasingly evident that dopamine has a function in its own right as well (Blaschko, 1968).

Among the most modern of drugs are those used in the treatment of mental disease. Broadly, these drugs fall into two main categories: the antidepressants and the major tranquillizers. Antidepressants are used in mental depression. A pharmacological action common to them is the ability to increase, in one way or another, the effective concentration of the brain amines. The major tranquillizers, or correctly, the neuroleptics, are mostly used in states like schizophrenia where there is a component of abnormal mental overactivity. The pharmacological action shared by the different neuroleptics is the depletion, or the interference with the intercellular transport, of brain amines at various sites. These observations have prompted investigations into the possibility of a correlation between the amine levels in the brain and mental disease.

The neuroleptics deserve further attention. Examples of these are :

reserpine (now more or less abandoned as a neuroleptic drug)
phenothiazines (e.g. chlorpromazine, "largactil") and
butyrophenones (e.g. haloperidol, "serenace').

Chlorpromazine and haloperidol share other pharmacological properties. One of these is their potent central antiemetic action (Edmonds-Seal and Prys-Roberts, 1970).

The vomiting centre in the medulla may be activated normally by afferents arising from diverse parts of the body. Some important afferents arise in the chemoceptive trigger zone, or CTZ, which is located in close proximity to the vomiting centre. The CTZ is the site which is stimulated by centrally-acting emetic drugs such as morphine and digitalis. Neuroleptics produce their antiemetic action by selectively blocking the CTZ (Fig. 10).

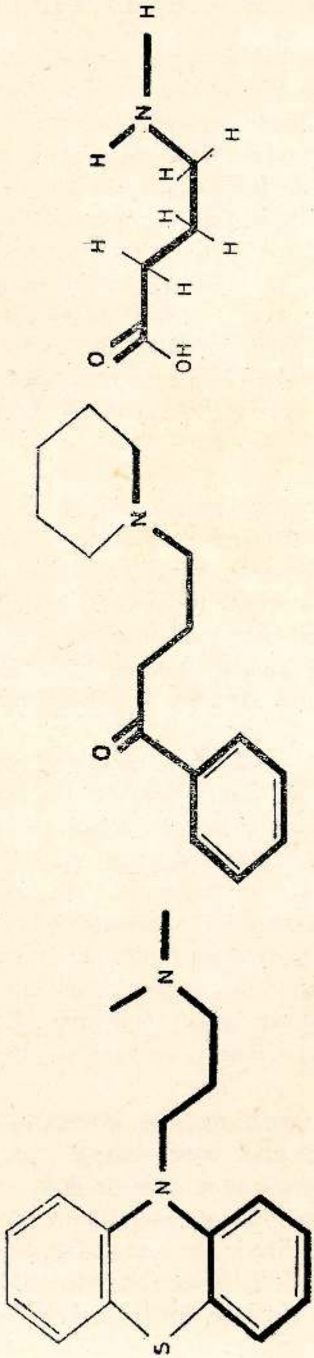


Fig. 11. Chemical structures of a phenothiazine, a butyrophenone and GABA.

One of the areas in the brain where dopamine is concentrated is the CTZ. It has been suggested by Janssen (1967) that, normally, stimulation of the CTZ releases dopamine which is turn activates the vomiting centre. Janssen has explained the antiemetic action of the neuroleptics on the basis that these drugs prevent the dopamine, released by CTZ activation, from combining with the receptors in the vomiting centre. According to Janssen the mechanism of this interference is as follows. Gamma-aminobutyric acid, GABA, in the brain is normally responsible for maintaining the permeability of brain cells including the receptors. There is a chemical similarity between GABA and the neuroleptics (Fig. 11). By competition with GABA the drugs render the membrane impermeable.

A striking feature about the neuroleptics is their liability to produce symptoms of Parkinsonism as an adverse effect; this is common to all neuroleptics. Parkinsonism is a chronic neurological disorder characterized by tremor, rigidity and excessive salivation; mental depression may also be present. The disease may be due to cerebral vascular changes, viral infections, clinically-used drugs, and poisons. It may also be idiopathic.

Convincing evidence has now accumulated indicating that the reduction of dopamine in certain areas of the brain may underlie the symptoms of Parkinsonism irrespective of the cause. In the brain the nigrostriatal areas influence control of muscle tone, posture and movement. Histochemical fluorescence techniques have revealed high concentration of dopamine in the nigrostriatum. The amine is believed to have an inhibiting function here (Hornykiewicz, 1966). Brains from autopsy of patients with idiopathic Parkinsonism have shown gross depletion of the nigrostriatal dopamine (see review, Calne and Sandler, 1970).

As a consequence of such findings, dopamine was tried out in Parkinsonism. The results were disappointing. It was then realized that ineffectiveness of dopamine may be due to the fact that amines of this type do not readily gain access to the brain. The precursor of dopamine in the body, L-dopa, which is not an amine, was the next logical choice for trial. L-dopa became the first promising drug in a century for the management of this trying disease (Calne and Sandler, 1970). Here we can say that we infer that L-dopa acts in Parkinsonism because the drug gives rise to dopamine in the brain. The effectiveness of L-dopa in Parkinsonism might suggest that in other states, where biochemical derangements occur, a similar therapeutic approach may prove fruitful.

In phenylketonuria, phenylalanine in the food is not metabolized in the normal manner as the appropriate enzyme is genetically absent. High concentrations of phenylalanine appear in the blood of the affected individuals who also excrete phenylketones in the urine. The disease is characterized by mental retardation, the immediate cause of which is obscure. Atopic dermatitis, and sometimes symptoms of Parkinsonism may also be present. At the present time there is no specific drug therapy ; the condition is managed by the institution of a phenylalanine-restricted diet, a regime which is not without risk to the patient since phenylalanine is an essential aminoacid. A hypothesis has been put forward (Kottegoda, 1970 b) that the defect in phenylketonuria eventually results in a deficiency of dopamine and similar amines in the brain and elsewhere. It is suggested that such a deficiency could account for most, if not all, of the manifestations of the disease. On this basis L-dopa has been advocated in phenylketonuria.

I have discussed some mechanisms of drug action not merely to illustrate, so to speak, some aspects of the philosophy of pharmacology. It has already been pointed out that one of the distinguishing features of modern medicine is its continued interest in the mode of action of drugs. As you know, one of the by-products of such studies has been the insight that has sometimes been provided into some bodily processes, especially in the brain.

There are in, my view, other implications. At the present time more drugs are consumed by more people than ever before in man's history (Baker and Dacey, 1970). To modify Wilson's (1966) analogy, the buggy cart and the bottle of medicine of old are fast disappearing. Their places are being taken by the motor car and the modern drugs respectively. Both these, though efficient, can do much harm if they are not used with proper care.

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Naturally, potent drugs are not prescribed by rote. Today's physicians should be (Laurence, 1966), and the majority of them are, equipped with some knowledge of the drugs they use, in addition, of course, to the dosage. But at present time this knowledge alone appears to be inadequate.

You are aware that in the recent past a new chapter has been opened in medicine. The title of this fast-expanding chapter is " drug-induced ", or " iatrogenic " disease. Perhaps one method of limiting the pages of this chapter is for the physician to have some broad idea of the mechanisms of the action of the modern potent drugs. This may be taxing the busy practitioner. But it is possible that such knowledge may help him further to handle a drug in such a manner to reduce or avert the harmful effects that it may induce in the patient.

If I were permitted to take the liberty of fashioning Bernard Shaw to suit my context, I would say that just as the difference between a flower girl and a duchess is not so much how they behave but how they are treated, so also the extent of drug-induced adverse effects will depend not only on the properties of the drug themselves but also on the manner in which the drug is handled by the physician who prescribes it.

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SECTION B—AGRICULTURE AND FORESTRY

Presidential Address

ACHIEVEMENTS AND UNCERTAINTIES OF A PLANTATION INDUSTRY

by

U. PETHIYAGODA

The choice of subject for an address of this type poses a dilemma. One could select a subject from one's own speciality in the interests of attempting to be authoritative, but at the risk of profoundly boring one's audience. Or, one may settle upon a subject of general interest but then takes the chance of saying little that is original or not already well known. I have chosen the latter alternative as the lesser of the two evils.

I have chosen to speak about the tea industry primarily because I am associated with it. Secondly, I believe it serves as an appropriate model for illustrating the comparatively high level of organization that it displays. I shall also try to indicate how this very organization has imposed certain weaknesses upon it.

A little over a hundred years ago, an enterprising and innovative coffee planter-James Taylor by name-was on the thriving estate, Loolecondera in the Hewaheta District. In the year 1869, he received and planted out on an extent of 19 acres, a batch of Assam tea seed procured from Calcutta. This tea stands to the present day and marks the momentous beginnings of an enterprise which was to have such a profound impact on this country. Although desultory attempts at planting the crop on a small scale prior to this year are on record, the credit for a planting with commercial intent is rightly assigned to James Taylor.

Even before this event, plantation agriculture was not new to Ceylon. As early as the Dutch times, Ceylon was an export producer of cinnamon and by the late eighteenth century, this country was producing the world's entire supply of this commodity. Until 1769, the Dutch were content with gathering the crop from trees growing wild, mainly in the jungles of the Kandyan King's territory. Reacting to periodic pressures from the King, the Dutch Governor decided to open the first cinnamon plantation in what is today Maradana.

The plantation successor to cinnamon was coffee which made its entry in 1823-25 on a history which was fated to be very brief. It was in 1844 that the first batch of labour (numbering 14) was recruited from South India for work on the coffee plantations. The growth of coffee was phenomenal and by 1869 (the year of the coffee rust), the extent was 176,000 acres with an export crop of a little over a million hundredweights. Ten years later, the extent had risen to 275,000 acres although exports had halved.

The decline of coffee due to the fact that the hopelessly uncontrollable coffee rust (*Hemileia vastatrix*) had taken a firm hold, and the increase in coffee acreage marked the desperate attempt of the planters to counter the devastation by increasing the productive acreage. Nevertheless, production continued to dwindle—underlining the futility of this approach.

It is sometimes stated that tea was rushed in to replace the fast declining coffee crop—but the dates reveal that this was not strictly so. It is an interesting reflection that the progressive planters of the time, when coffee was king, with not a limit in sight for its continued prosperity, yet experimented with ideas of diversification-prompted perhaps by a faint possibility of over-production.

While tea was making its small beginnings, another lucrative alternative was cinchona-which enjoyed a short but nevertheless highly profitable life.

Undoubtedly, the collapse of coffee spurred on the rapid expansion of tea. Not least among the attractions was the ease with which the assets and the organization of the coffee industry—the land, personnel and handling and marketing techniques and institutions could be deflected to serve the needs of the newcomer.

For a vivid and highly readable account of the origin and growth of the tea industry in its many aspects, one cannot do better than to turn to D. M. Forrest's "A Hundred Years of Ceylon Tea ". This book was commissioned by the Ceylon Tea Propaganda Board to mark the centenary of the first commercial planting of tea in 1867. It is a rare treasury of information on the history of the industry—the background against which it arose, the personalities and institutions that were associated with it and the manner in which it developed its techniques, systems and practices.

Almost simultaneously with the expansion of tea, was developing another major plantation industry, rubber-with the first introduction of plants in 1876. I shall have to omit reference to rubber as also to the third leg of the tripod, coconut. However, it is my hope that the remarks I make will not be entirely without relevance to these two important partner industries.

The economics of the tea industry have recently been the focus of many studies and surveys carried out internationally by bodies like the FAO and by individual producer countries. The bulk of data, statistics, analyses and conclusions that has resulted is bewildering. Inexpert as I am in this area, having chosen my present subject, I shall be obliged to make limited forays into this territory but wish to seek the experts' indulgence by admitting my ignorance prior to revealing it.

Achievements of the Tea Industry

Today tea occupies about 15% of the total area under crop cultivation in the country. It accounts for a little over 60% of the total export earnings and along with other agricultural production makes a contribution to the Gross National Product of the order of 35%.

The social consequences of the industry have been equally striking. While detailed consideration of such aspects is beyond my scope, suffice it to mention such benefits as the present road and rail systems and the employment and taxation revenue generated as some of the associated developments. Rural landlessness and the social problems generated by the implantation of a large foreign labour force are among the industry's undesirable offshoots.

One of the most conspicuous features of the tea industry is its orderliness. This extends beyond the smooth neatness of a well tended field with the passion for such practices as clean weeding, fastidious pruning and level plucking, to the organisation of the managerial and fiscal arrangements of the trade.

The tea industry began and developed as a strictly profit-conscious enterprise. It has accordingly ordered its managerial techniques and organizational arrangements to suit this end. A distinct heirarchical linealogy has been evolved. In this, the Superintendent or Estate Manager forms the central pivot. Above, below and around him move the Visiting Agent, Agents, Directors and Owners, Assistants, Field Staff of various categories and functions, suppliers and advisory services on fertilizers, soil, pest, disease and weed-control chemicals and the tasters and brokers as the participants in the sale of his produce. Although it has its shortcomings, the system has by and large, worked well enough to ensure a sustained expansion and prosperity of the industry.

Contentment and a close involvement in the industry's fortunes being a help to the effective pursuit of the profit motive, the provision of incentives is well organized. This is by way of bonuses, career opportunities and such fringe benefits as housing, assistance in social matters and the provision of generous leave facilities. Various organizations such as the Planters' Society and Planters' Association further professional well being and security, providing assistance in several aspects of the industry's working. A recently established Institute of Planting seeks to provide training facilities to new comers as well as those already in planting. The Tea Research Institute provides service through seeking and disseminating answers to agricultural and other technical problems.

Profit-consciousness has logically led to the development of rather special costing procedures. Here the tea industry resembles any other non-agricultural manufacturing industry. All expenditures however small, ultimately translate into a component of the cost of production, as so many cents per pound of made tea. This has two immediate advantages. Firstly, at any given time, it furnishes a ready reckoner for an estimation of the way an estate is working–whether at a likely profit or loss. Secondly, it ensures a tight control over outlay and efficiency in the way materials and labour are being employed. For example, almost every task on an estate is subject to norms and adherence or departure from these are subject to constant checks and correction.

As in any well organized enterprise, each functional personality fits into a neatly ordained niche. At all levels, tradition and practice have led to a clear recognition and definition of role. While all have undoubtedly contributed to the overall effectiveness of the system perhaps the Superintendent merits special attention.

In my conviction that the Superintendent, by virtue of his training and experience embodies an outstandingly useful combination of skills and expertise that would be vital to any task of overall agricultural development facing this country, I shall spend a few moments in considering him.

The complexities and refinements that have developed around the industry have all closely involved him. Tea is labour intensive, its field management is highly specialised, processing is carried out on the property as also the business of maintaining records of expenditures and proceeds. Being to this extent self-contained and often remote, a multitude of skills and qualities are expected of a Superintendent--firmness combined with tact, in the maintenance of discipline and efficiency among the labour, and consideration in the provision of their many welfare benefits and when the formula fails to work on occasion–qualities of personal courage and the ability to do right in an emergency. This is where athletic ability possibly becomes directly relevant ! A fair background scientific knowledge is needed to cope effectively with the complexities of efficient crop mangement and manufacture. A flair for operational control and mechanical ability are assets in running the factory. Finally, as the custodian of costly machinery and on occasion, large sums of money, a high level of integrity and some accounting knowledge are expected. This is the ideal model–and of course imperfections are not rare. However, by training and tradition the Superintendent does represent a synthesis of talent, expertise and attitudes to work, that it would be a national tragedy to spurn.

Apart from this, I have spent some time to indicate the hard work that is involved in the production of this crop. This heightens the disappointment and frustration in the participants when the industry in a relatively brief space of time, has changed from a state of booming prosperity to one of doubt and uncertainty.

By the turn of this century, tea had become the main export-crop of Ceylon. Until the 1920's comparatively little was being done by way of scientific investigation of the crop. This was in the hands of the Department of Agriculture whose concern for tea was necessarily diluted by occupation with a multitude of other crops. Following on the demands of the Planters' Association, the necessary Ordinances for the establishment of a Tea Research Institute were passed in the State Council in 1925. The degree to which scientific research has proved demonstrably effective is an achievement on which I must dwell for some time. The TRI at the present day comprises ten technical divisions at its headquarters and four smaller outlying regional stations. It enjoys recognition as the premier centre for tea research in the world.

While there are several reasons for its extraordinary success, I would mention just two. Firstly, being financed directly by a cess on the exports of the industry, it has always tended to be closely tied to its prosperity. Secondly, being a commodity-based Institute, it has been able to pay the most intensive attention to problems associated with almost all aspects of the industry.

The research activities of the TRI are directed towards two main ends. Firstly, reducing production costs and secondly, improving the quality of the product. These would appear to be two obvious means towards increasing profitability. However, considering the special nature of tea, it would be apparent that for these objectives to be effective, certain other conditions must also be fulfilled. Cost reduction is directly profitable only if selling price remains constant or declines by an amount less than the savings effected. Determinants of sale price are so vastly more complex than the inherent quality alone that price cannot be shown to directly relate to this factor. Further, as improvements in quality often necessitate higher standards, closer supervision, lower productivity and enhanced production costs, the one objective often tends to lessen the impact of the other.

The history of the tea industry has been one of crises and recoveries. Restriction of production was resorted to in 1901, 1917, 1920 and in the early '30's. However, none of these were expected to be permanent and it is against this background that the TRI developed. It saw as its main role, an increase in total production and of productivity per acre. As a consequence, the agricultural aspects of tea culture have attracted the greater emphasis. It was also perhaps in recognition of the priority need to expand production that financing the Institute came to be based on a cess imposed on the poundage of tea exported, rather than on a parameter relating to sale price or overall profitability of the industry.

Research relating to market factors and other economic considerations have received greater attention from such organizations as the Central Bank, the Planters' Association and the Tea Propaganda Board while the TRI has not developed the institutional framework for dealing with such questions.

In view of the unfavourable financial situation that confronts the industry, intense attention is paid to possibilities which may lead to a reduction of costs, particularly of foreign exchange. This urges the review particularly of the use of fertilizers, fungicides, insecticides and herbicides–all of which involve large amounts of foreign expenditure. In the field of fertilizer usage, economising has been the primary operative concept. The omission or reduction of phosphates and magnesium which have so far shown little relation to yield, and to a lesser extent of potash and nitrogen, are embodied in the Institute's more recent fertilizer recommendations. There has been a shift from the objective of maximum crop, to a more prudent one of optimal returns from fertilizer outlay.

In economising on applications of fungicides and insecticides, attempts have been made to assess crop losses occasioned by different levels of infestation as a first step towards evaluating degrees of control consistent with tolerance levels for infestation rather than complete eradication of the pest or pathogen. In the use of herbicides, a foreign exchange cost is substituting for a rupee cost and the approach has to be cautious.

In the severe competition that exists between individual holdings even within the country, distinctions between national and individual profitability need to be borne in mind.

Research has served the tea industry well. In particular, project orientated effort, of which the best example is the control of blister blight in the years following the second world war.

It is tempting to presume that a commodity-based research Institute is the most effective means of ensuring the best application of science and technology to agriculture. Crop-based research institutes appear primarily to be a tropical phenomenon and are a rarity in temperate agriculture. The virtues of basing research activity and organizations on conceptual lines or disciplines rather than on specific crops have apparently been long recognized in the West. As examples I may cite the United Kingdom, where in recognition of the agroclimatic feature of a low light intensity and duration at the two ends of the crop growing season, problems of maximum sunlight utilization have centrally influenced the choice of agricultural research priorities. Likewise, Israel is deeply committed to research on problems associated with drought and salinity whilst the Netherlands concentrates upon the maximum utilization of the short growing season, in selecting its research projects.

Where an agricultural crop has been correctly chosen and is seen to possess the scope for rapid and extensive expansion, a crop research institute is possibly the best arrangement. This offers the prospect of close and continuous attention to the many problems that are likely to arise during this phase. Where a new area needs to be developed or an agricultural pattern to be modified, the choice would clearly be a concept-based organization. While the one is apt to seek the situation to suit the crop, the latter is better adapted to finding the crop to suit the situation.

Does the cultivation of tea represent the most productive use of land and climatic resourses? Under the best conditions, crops harvested amount to about 12-15 tons of fresh shoots per acre per year. This is high and consistent with the high photosynthetic efficiency of a crop that covers the ground and absorbs virtually all the sunlight that falls upon it.

Tea in Ceylon is one of the most extensive monocultures of a perennial crop in the world. This was doubtless due to its success beyond expectation in its early years of expansion. It was a well balanced partnership between crop and environment. What are even today the best areas for its cultivation were among the first to be planted with the crop. This fortunate circumstance and the extreme profitability of tea led to its explosive spread–even as is today being repeated in the newer tea-growing areas in Africa. As a result tea was planted in almost any location with the slightest prospect of suitability. Concepts of ecological suitability and the hazards of large contiguous areas under the one crop, were evidently either unknown or of little concern to the pioneers.

Serious reservations can today be entertained about the wisdom of such uncontrolled expansion. A perennial crop with a life expectancy exceeding a century, poses serious problems of an uneasy permanency and inflexibility. Crop rotation and other concepts of soil husbandry either cannot be employed or have been overlooked. Mixed cropping as on a temperate fruit farm combining pastures, offers limited scope.

Plantations have become less sensitive to such factors as soil erosion on steep slopes. Severe destruction of organic matter and heavy losses of topsoil have often led agriculturists to regard this as the foremost threat to the agricultural viability of this crop.

In addition, it is not unlikely that large extents under a crop of the nature of tea must have influenced rainfall and wind climates and exerted an impact on other agricultural areas distant from the tea country.

A word about present day " problem areas ", in particular the Mid-Country. Through usage, this is the area of tea that lies between the 2000 and 4000 foot contours above and below which lie the Up-Country and the Low-Country. The Mid-Country is the region on which the present trials and tribulations have fallen the heaviest. It is the steepest zone on average and is the meeting point of pests, diseases and climatic problems of the other two regions. It therefore suffers from most of its neighbour's ills and only benefits a little by slightly moderated disadvantages. These are apparently the reasons for the marginal performance of tea (as indeed perhaps of many other crops) in this region. However, it behoves us to remember that " marginal" qualifies above all else, the wisdom of ourselves and our forebears in choosing to plant such areas in tea.

Uncertainties that face the Industry

It is with great trepidation that I venture into this heavily trodden area. However, since production problems are apparently minor in comparison with those of marketing, I am obliged to consider what appear to be certain features relevant to the position of tea as a market commodity.

Uncertainty is the dominant mood of the industry at the present time. The recent history of Ceylon's tea industry reveals a distinct decline in profitability–whether measured by average sale price or total foreign exchange earnings. The many causes to which this trend is ascribed may be divided into 'basic' causes and 'contrived' causes. The major one of the basic causes is that world production of tea has grown faster than world consumption, leading to over-production. Against this argument is the fact that there is apparently no stagnation of unconsumed tea nor have any producers been obliged to destroy any of their production. All tea has sold, but at a steadliy declining price from the peak reached in 1955. It is also somewhat unconvincing because such claims have often been made on earlier occasions when recovery has nevertheless followed such lean periods without curtailment of total production. Of the contrived causes, the main suspicion is that producer interests are being sacrificed in favour of those of the providers of the rather long and involved chain of services that the product traverses on its way from producer to consumer.

Both types of factors are probably operative and contribute to this decline. A weakness of the industry is that most price determining factors are beyond the producer's control. The possibilities of an improving situation are based on predictions and hopes that may themselves not be realised or even if realised, may be nullified by other unforeseen circumstances.

The bulk of tea production has always been sold by auction. There has been very little change over the last century, of the associated traditions and practices. As it appears at the auctions in the world's several such centres, tea is a highly differentiated product. In contrast, the tea that is sold to the consumer is claimed to maintain a high degree of consistency, even being specially blended to suit the mineral and other characteristics of the water supplies of particular regions. Whatever the acceptability of this rather extraordinary claim, it remains a central cause for wide fluctuations in price.

The ultimate consumer market is a highly conditioned one and it remains a moot point whether what is offered as a blend in contrast to 'straight' teas is what the consumer really prefers. This question will probably be answered if a greater amount of unblended tea can be made to reach the major markets.

In few areas of commodity trade does one encounter such a tangle of distinctions between producer capabilities and consumer requirements. Manufactured tea varies according to country of production, elevation and locality, method of manufacture and 'quality' in the broad sense. Market and consumer preferences likewise change according to the destination, mode of presentation (whether in packets or tea bags, for example) and the the blenders' requirements for standardisation of his particular type of blend. To further complicate the picture, several of these factors are themselves under continual change and it is nearly impossible to predict future developments. Superimposed on this, changes in shipping, insurance or tariff arrangements make an impact on price and profitability.

Against such a background it is difficult for producer countries (whose own objectives may be divergent) to determine how much and what type of product they should offer.

The tea trade is delicately sensitive and fears of reaction and imbalance bedevil producer attempts to interfere or sometimes even inquire, into certain aspects of the system.

Studies by Jeyapalan and Jayawardena of the Central Bank on 'Some Aspects of the Tea Industry' illustrate some of the complexities that surround the price determination of tea. In a series of articles they have examined the seasonality in World Tea Production, features and trends in the World Trade in Tea, product differentiation of tea by quality, and some features in the structure of the UK tea industry and their probable impact on the general level of tea prices.

They also incidentally arrive at the oft-suspected conclusion that " it seems more likely that blending serves a more important function of enabling the blender to keep retail prices uniform and low by altering the composition of the product.

It is evident from their studies that a vast interplay of many considerations is relevant to price. It is also seen that some of the diagnoses generally made and hopes entertained, do not bear close scrutiny.

For example a recent temporary decline in tea prices at the Colombo Market elicited the explanation that the last summer in Britain was hot, the implication being that this induced more people to turn to alternative cooling beverages. It is interesting to reflect that had the prices gone up, the same explanation could have been offered with equal apparent validity. It will be conceded that it is insecure to base a huge proportion of our national economy on the well known unreliability of the British weather.

It would appear that the special vulnerability of tea as a commodity stems from three basic causes :—

(*a*) it is a perishable product,
(*b*) it is non-versatile, and
(*c*) it is not an essential commodity.

Perishability

Conventional black tea does not keep well and in storage, tends to acquire undesirable flavours and to progressively lose desirable ones. The main hazards are moisture (and resulting moldiness), high temperatures and exposure to ' tainting ' odours.

Quick disposal of the produce is thus obligatory. This immediately places the producer in a position where his sale price is determined by the collection of factors prevailing at that particular time, in the auctions. In contrast with many other products, he is not able to phase the release of his produce in such a manner as to secure the best possible price. Advantages in seasonal appearance of desirable characteristics are also reduced by the release of such quality teas by several producers simultaneously.

Apart from this, storage space problems are a further restriction. A 1000-acre estate with a production of 1000 pounds per acre, would be averaging around 3000 pounds of manufactured tea per day. It is impractical to provide for the storage of such an output for any appreciable time.

The manner in which tea is packed for export is one illustration of the reluctance to change. The tea chest with its tinfoil lining has changed little in the last century. It is possibly not the most satisfactory and certainly not the cheapest arrangement.

Experimentation on the most satisfactory processing, packing and storage methods that would improve keeping qualities continue. Exploration of means of curtailing the time spent in warehouses may also be rewarding. Such practices as 'stockpiling' of tea in some consumer countries suggests that better warehousing techniques enable this to be done.

Non-versatility

Tea is not a versatile product and in that sense is considerably weaker than rubber or coconut where the product serves as the starting point for locally based industries.

In the case of tea, the possibilities are limited to either altering manufacturing methods leading to unorthodox forms like green tea or instant tea or making use of the product or the raw material for extracting other types of end products.

North-East India and East Africa produce mainly a non-orthodox black tea by a manufacturing process referred to as CTC. These teas possess attributes which make them more suitable for use in tea bags and it is this market which shows the greatest preference, for them.

While prices for black tea have steadily declined in recent times the prospects for green tea have apparently brightened. This prospect for diversifying manufacture deserves attention. Likewise, instant tea is a proposition that has attracted research efforts in this country since 1959. Apart from considerations of greater acceptability and competitive strength against rival beverages, this form may have better keeping qualities and perhaps also be more amenable to quality control. This overcomes two important disabilities of conventional black tea.

Modern processes of instant tea commence from green leaf. After extraction of the juices, the large amounts of residue would contain a certain amount of crude protein, cellulose and other constituents. The prospects for the profitable recovery of some of these are attractive. Leaf protein is acknowledged as a useful dietary enrichment and much work on the extraction and use of proteins from leaf is being done in other countries-notably in the UK and India. Cellulose and other components in the leaf residue may also prove useful. These possibilities are considered alongside the main project.

It may even be necessary to consider the possibility of using the plucked tea shoots directly for processing in these ways, should crop restriction become necessary.

Non-essentiality

It is often stated that an increase of effective (and generally costly), propaganda is one of the ways towards improving the prospects for tea. This has proved difficult in the present plight of the industry and it is unlikely that the same outlay on promotion that producers of more profitable beverages are able to provide, will ever be feasible for tea producers.

The need for such propaganda is a reflection of the non-essentiality and hence vulnerability of this commodity. More especially, it emphasizes the imprudence of the present heavy dependence of our economy on a commodity which requires such hard sell techniques for its sustenance.

Propaganda takes us on to the subject of predictions, presumptions and slogans. This is an area where the greatest caution is required in the evaluation of future prospects.

Let us consider just one presumption. It is often argued that improvements in living standards in consumer countries may contribute towards a greater demand and better price for tea. Is this likely to do so? It would seem just as likely that affluence encourages more sophisticated investments and even if an increase in consumer expenditure is registered, it would be hardly likely to affect such a marginally essential commodity such as tea. It is just as likely that the many higher priority or more desirable items competing for this extra wealth, may bring about the reverse results. For producer countries it would be well to bear in mind the cold truth that tea is a commodity that many people can do without.

The dilemma that faces us is that the industry nevertheless contributes a massive component of our foreign exchange income. Being a perennial crop plant, tea is inflexible to rapid change. This underlines with great validity the obligations for very long term planning of land use.

An industry in distress reacts in certain predictable ways.

(i) It seeks to cut its costs.
(ii) It attempts to improve its sale price.
(iii) It considers diversification.

I have dealt with the first two of the above factors in other connections. Economies on estates have meant a large scale cut back on capital investments. Fortunately for the existence of schemes to subsidise factory developments and replanting, the impact on these two sectors has been lessened. Cultural practices have been subject to cost reductions. Cheaper forms and lower levels of fertilizer, the omission of practices like forking of the soil, the acceptance of less stringent standards of weeding and other field operations are among the ways being sought. Naturally many of these curtailments have an effect on crop performance and the research worker's role has been to identify permissible economies and to advise on possible side effects. Standards have suffered and as a general principle, it is dubious whether such steps have had the desired effect.

With the highly complex trade and with its inter-relationship and imperfections, sale price may well relate to cost of production. This aspect merits scrutiny as it is so central to financing at the producer's end.

Tea at the auctions is priced in a highly subjective manner through the Taster. It is subject to wide fluctuations in price from one batch to another. There are several puzzling features that surround this activity, not least of which is the contrast between the wide price differences between lots and the close range of biddings within any given lot. Some of the Tasters criteria of evaluation bear little direct relevance in the final cup of tea.

Controlled therefore by environmental factors in the field, factory techniques and market needs that are not easily identifiable, it cannot be hoped that complete stability of price will ever be realised. The industry has attempted to respond by tailoring the product to what it expects buyer's requirements to be. That this information is difficult to define is clearly apparent.

On the assumption that certain attributes like 'flavour' and 'quality' are preferred by the market, manufacturing procedures, plucking methods and the selection of clones are consciously directed towards this end. However, such attempts generally result in a sacrifice of quantity and again pose the possibility of an increased unit cost.

An aspect of tea is that the product marketed is virtually in a penultimate stage of preparation on its way to the ultimate consumer. The important step of blending is out of the producer's hands. This is an avenue that has been considered as also a means of supplying the retail market with 'straight' teas too.

This leads me on to the last point I wish to consider. This is diversification. As already indicated, tea is not a commodity likely to lend itself to much in the way of innovation. Possible market reactions always loom as a dark deterrent.

Whether the present setback to the industry's fortunes is permanent or not, it is clear that the diversification into other crops of a large area presently under tea, must occur. The potential for very high production that vegetatively propagated clonal tea offers and the economic need to intensify this production, is bound to free a large area of land (sometimes estimated as high as 400,000 acres) for other types of crops.

This represents the most massive opportunity that this country has had for a planned development of its agriculture. It is to the already established agricultural industries that we shall need to turn for guidance on the strategy to be adopted. It is partly to illustrate what potential the tea industry already possesses for this task, that I have selected the subject of my talk. I hope I have succeeded, at least in some measure, in pointing to some of its strengths and weaknesses, organizational arrangements which may profitably be emulated and equally some aspects to be avoided. I have attempted to show some features that make tea a weak commodity, which must be borne in mind in the selection of alternatives.

The approach it seems to me, should be uncompromisingly project-orientated. Institutional, financial and personnel arrangements must all be geared to such a strategy. A land utilization pattern based on the available data on soil and climate, forms the logical scientific base.

It is normal to identify the land area available for diversification with present day "problem areas". The limitations to agriculture in this area have been briefly outlined earlier. It is worth considering whether this forms the most suitable base on which to launch a novel and important concept. The land and environment is agriculturally marginal, the people on this land, have suffered a period of unthrifty and demoralizing agricultural activity. While the need here is probably the greatest, it is debatable whether this is the medium on which a new idea and approach is likely to flourish.

The choice of new crops is not easy, there being ecological and economic considerations of equal urgency and importance. Agronomically, the ideal would be those crops which represent the best possible synthesis of soil and climatic potentials, ensuring equally, proper utilization of these factors and their proper conservation. Economically, the maximum productivity and foreign exchange earning or saving potential.

Food crops, paper, pasture and timber have been chosen as obvious candidates. Perhaps most advantageously, an optimal combination between them.

Among the assets available, besides land and climate I would enumerate the scientific data and personnel for carrying through the task, the executive and managerial talent the tea industry already possesses with its familiarity with profit-orientated crop management and the availability of appropriate trained labour. Together these represent an enormous prospect for success.

It seems that the need and philosophy of crop diversification are already well appreciated. What is now necessary is an effective provision of data on potentials for other crops, planting material, agricultural and processing advice and equipment, and arrangements for marketing.

The priority need of the moment is an extensive and purposeful crops-screeing programme. A readiness to explore unconventional crops is very necessary. It is well to remember that many of the crops that are today basic to commerce have moved half way round the globe from their centres of orgin to find the areas of their most profitable use.

Another aspect which one hopes will attract attention during this process is the better utilization of the potential food plants we already have. Surprise has often been expressed on the non-utilization of highly productive tropical plants like jak and bread-fruit. I may also mention as an example, that considerable investigation is being done at some European research stations, of the tropical weed species *Amaranthus viridis* (Keerai or Kura Tampala) for its potential use as a pot herb to supplant the temperate Spinach.

The wide gap that exists between desirable and available food, clothing and other agriculture-based amenities for our own people and the need to fill this gap, offers a vast potential for the absorption of the fruits of a crop diversification scheme.

Crops capable of being processed upto the stage of finality within this country itself are obviously attractive. They offer extra employment and would be less susceptible to price manipulations.

Readjustments of labour within tea estates is soon likely. The differences in labour needs for various crops will be one means of accommodating the problems arising from this redistribution.

Crop diversification in the tea areas is bound to exert an impact of the greatest magnitude and is perhaps as important an event as the introduction of tea itself. Success is economically vital and the prospects for a massive planned agriculture are exciting.

In conclusion, I wish to express my thanks to the members of my section-Section B for having bestowed on me the honour of the Presidency of the Section for the past year.

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Presidential Address

PLANNING FOR THE FULL REALIZATION OF THE POTENTIAL BENEFITS FROM IRRIGATION PROJECTS.

by

P. H. PERERA

Introduction

It is customary for a presidential address to deal with a topic with which the president has been closely associated. If I may follow the same convention, the subject of my address will surely have to be " Irrigation ". But, irrigation has now developed into a vast subject encompassing not only the technical or engineering aspects which are of interest only to those who are actively engaged in this field. It also includes aspects which are of great significance to most of us, particularly in the context of planned development at the present time.

Therefore, I have selected a topic for my address today which is closely related to those other aspects of irrigation, namely, the economic and social aspects. When we consider these two aspects, we are really concerned with making irrigation development successful, or in other words, the question of deriving the maximum possible benefits from irrigation development while, of course at the same time, preventing any adverse effects likely to be created.

It is only quite recently that the attention of planners has been drawn to the poor returns we have derived from the heavy investments made on irrigation over the past several decades. A review of past development now seems to indicate that we have failed to realise not only the full potential economic benefits but also other social benefits such as, for instance, higher standards of living of the farmers.

I feel it is appropriate to quote here the following comment from a recent United Nations publication to show that this has not been a problem peculiar only to Ceylon :—[1]

'The improvement of human welfare is generally accepted as the essential, over-riding purpose of planned development ; so far, however, national planning and development in Asia as a whole have yielded very meagre benefits in those terms.... One reason for this unfavourable and potentially explosive situation is the sluggish pace of economic growth (alongside very rapid population increases) in Asia as a whole ; a second related reason is the widespread neglect of social considerations in development planning—planners have tended to assume that social benefits will flow more or less automatically from an expanding economy, and that social aims must therefore take low priority until rapid and continuing economic growth has been secured. This attitude....overlooks the crucial part played by social change and dynamics (as distinct from the enhancement of material welfare conditions) in providing the driving force of economic growth."

This was also clearly brought out by every participant at a recent F.A.O./U.N.D.P. Seminar on " Measures to Accelerate Benefits from Water Development Projects by Improved Irrigation, Drainage and Water Use at the Farm Level " held in Manila, Philippines, which I had the good fortune to attend.

It is now generally accepted that every irrigation project is essentially a means for the agricultural, economic and social development of a given area through the most effective utilization of the available land, water and man-power resources, raising the standard of living of the farmers and enhancing the economy of the country as a whole.

Therefore the potential benefits to be derived from irrigation projects include both economic and social benefits, and the full realization of these potential benefits in the shortest time from a given irrigation project can be achieved essentially through careful and comprehensive planning.

In this paper, I propose to first examine briefly the background to planned irrigation development in Ceylon, assess the utility of the development works carried out in the past and, finally, to outline the current trends in planning which are aimed at the full realization of the potential benefits from irrigation projects of the future

2. Background to Past Development

I do not propose to go into the early history of irrigation but I will mention a few salient features. The policy of irrigation development initially was to carry out improvements to village irrigation works scattered throughout the Island with the objective of exploiting their water conservation potential to the fullest possible extent for extending the cultivation within easy reach of the village farmer. Restoration and improvements to irrigation works became the responsibility of the Irrigation Department. The new policy governing irrigation development was directed at achieving three principal objectives—

1. To increase rice production.
2. To settle people in the new irrigation areas of the dry zone so as to alleviate unemployment and relieve population pressure in the wet zone.
3. Village expansion.

Difficulties in the import of rice during the World War II led to the rationing of the peoples' staple food. After the end of the war, the pace of development was accelerated and irrigation development was pursued with even greater vigour than before, while the planning was directed to achieve the above objectives. The land preparation and land development was also added as it was found that a large extent of land under Major Irrigation Works amounting to as much as 16,000 acres had not been cultivated due to lack of land preparation although irrigation facilities had been provided.

It will be seen that the irrigation development carried out for a long period had been aimed to achieve the above objectives. The first reflected purely an economic aspect while the others involved a number of inter-related economic and social aspects. However, the economic and social aspects were not well defined and adequately recognised, the planning of the past tended to concentrate rather more on the technical and engineering aspects than on the ways and means of ensuring the fullest possible benefits.

It may not be out of place if I make an attempt here to examine the criteria adopted at the time to appraise the feasibility of an irrigation project. In the case of village works, expenditure or a 'norm' on capital outlay per acre of land had been the criterion. These norms had been fixed on an ad hoc basis and had been progressively increased over the years as the cost of materials and labour gradually increased.

The 'Norm' commonly known as "Pro-rata cost per acre benefited" has been increased from original Rs. 250/- per acre to Rs. 500/-, Rs. 750/-, Rs. 1,000/- and finally in May 1970 to Rs. 1,500/- for small irrigation works, which are commonly known as Village Irrigation Schemes. The pro-rata cost did not vary for different regions of the country or on the basis of benefits to private lands, or state owned lands, existing or newly opened lands, single cropped or double cropped lands, irrigation, drainage, salt water exclusion or minor flood protection schemes or extent of net benefits.

Where the pro-rata cost exceeded the stipulated amount prevalent at the time, the chief revenue officer of the district made a special recommendation to the Director of Irrigation taking into account the need for the project for improvement of the socio-economic conditions of the locality. The Director of Irrigation then sought the approval of the permanent secretary of the ministry of irrigation to implement the scheme in spite of its high cost.

The major works were also judged on the basis of similar per acre capital cost in the early stages. Recently (1957), the capital costs including headworks, irrigation facilities, land development and land settlement were compared with direct benefits, i.e. production from irrigation over a period of 20 to 50 years as the case may be. Capital expenditure for investment on irrigation projects had been very arbitrarily fixed.

The first signs of change in planning irrigation projects emerged in 1948 when two irrigation projects, Gal Oya Scheme and Walawe Scheme were planned as multi-purpose projects. Gal Oya project was originally planned as Irrigation, Power and Flood Control Project, it was altered into a two-purpose project of Irrigation and Power at the construction stage, nullifying the effect of flood control by constructing a larger spillway.

Benefits from irrigation had been looked upon as import substitution since Independence. This is evident from the following sentiments expressed by the then Prime Minister, Rt. Hon. D. S. Senanayake on the occasion of the inauguration of the work on the Gal Oya Project.

"Gal Oya has become a house-hold word. It is symbolic of the New Lanka. May it obtain fulfilment speedily and herald the progress of our march towards self-sufficiency."

This was also the first project in Ceylon under which an attempt was made to introduce crops other than paddy viz, nearly 10,000 acres of sugar cane.

It is also interesting to note the progress made in the development of irrigated lands. About 400,000 acres of land were irrigated in the 84 year period from 1862 to 1946 and further 400,000 acres in the 20 year period from 1947 to 1966.

3. Assessment of Past Development

Before proceeding to outline the current trends in planning for future irrigation peojects, it would be appropriate to make a broad assessment of the irrigation developments that have been carried out over the past two or three decades in order to determine whether such development had led to the achievement of benefits commensurate with the costs involved.

The Report of the Farmer Committee[2] on its ex--post evaluation of the Gal Oya Project has been considered as being a severe criticism and a condemnation of the type of irrigation development than we have been accustomed to so far. The findings of this committee may also be considered very valuable in relation to defects not only in advance planning, but also, in the programming and implementation of major irrigation projects, resulting in long delays in the realization of the anticipated benefits. It has been found that the gestation period of irrigation colonization schemes has been 8 to 15 years for initial production to commence and 12 to 20 years for maximum output to be attained with the benefit cost ratio of 0.64 and an annual net financial loss of Rs. 357/- per acre.

A perusal of the Gal Oya project will show that work on the main dam began in March 1949 and was completed in November, 1951. The Irrigation Department responsible for construction of head-works handed over the works to the Gal Oya Development Board in November, 1952. The first colonists were settled on the left bank of the Gal Oya in 1950/51 numbering 296 displaced families from villages that got submerged or were taken up for development. At the end of 1954/55, 34 new villages had been established containing 4,780 families comprising 33,000 persons[4]. In succeeding years, the process of peasant colonization continued as the canal system was extended until by 1965, some 11,936 families had been settled. By September, 1967, the Board had completed irrigation facilities to 109,130 acres of new and existing lands and over 14,000 farmer families had been settled[5]. Table I shows the sequence and rate of provision of irrigation facilities from 1950/51 to 1966/67.

The evaluation committee has high-lighted the lack of effective communication between the farmer and the extension worker.

> "The poor yields to date and the failure to adopt techniques to soils, point to another significant conclusion—the failure of the Board's Agricultural extension activities to make sufficient impact on the colonists cultivation practices."

A socio-economic survey conducted in the left bank area of the Gal Oya Project by the River Valley Development Board (1965—1967) revealed that the average income per allottee was of the order of Rs. 2,200/- per year while two-thirds of the allottees earned less than Rs. 2,400/- per year. (See Tables II & III).

The general policy of colonization has caused a great deal of argument in regard to type of colonist and the relation between its costs and its benefits to the national income. In this connection, I may quote here from the first report of the Planning Committee of the Ministry of Agriculture and Food :—.

> "It can conclusively be shown that expenditure over large scale on schemes of land development, colonization and irrigation contributes much less to the national income than expenditure on replanting of export crops".

It further states—

> " Actual production in the average Dry Zone colony is under 16% of the total capital involved compared with 100% in Panjab Colonies."

Short-term Implementation Programme of 1962 drew attention to the poor benefit-cost ratios for Mahakanadarawa and Rajangana Projects which had been estimated as 0.56 and 0.67 respectively.

4. Current Trends in Planning

All these facts outlined above clearly signify that irrigation projects have not been planned for full realization of the benefits. Proper co-ordination of the objectives had not been done at the planning stages.

Irrigation is the farmers' means to influence the availability of water to plants and to completely control the water contents of the soil. Irrigation which also looks after drainage is therefore actually a part of agriculture and should be directed towards obtaining the objectives of agriculture and their planning, execution and operation must be geared to an integration of the engineering side with agricultural activities and socio-economic objectives.

Investment in Water Development for agriculture cannot be allowed to be unprofitable and the first objectives of such investment should be to obtain economic benefits, specially income from the farmers. This was clearly stated by the Hon. Maithripala Senanayake, Minister of Irrigation, Power and Highways in opening a seminar on Water Resources Planning recently. He said:

> " It would be appropriate for me to mention on this occasion that in planning water resources, irrigation projects may be so devised that short and long term measures may be made to supplement each other so as to ensure assured irrigation for all types of year round crops in an attempt to get maximum food production with the optimum utilization of available water resources."

The need for intensification of production and the need for diversification of crops which have been stressed require considerable change in planning of irrigation projects and agricultural practices.

5. Changes in the Engineering Approach

The planning and designing of costly irrigation projects should no longer be designed on empirical formulae such as water duty, evapo-transpiration, etc. but rather modern water use planning calls for a new type of complex judgement on water in relation to soil fertility cropping systems and crop returns. Thus physical surveys required for the planning and design of irrigation projects have to be designed on the actual consumption of water determined by research. Consequently, planning has to be started from the farmers' field. Consideration also must be given to what type of irrigation should be adopted. The methods of application will chiefly depend on the topography, soils, the crops to be grown, water management practices and economy in the use of water.

Facilities for removal of excess water, drainage and flood protection works will have to become an integral part of irrigation projects.

Operation and maintenance plays a vital role in the development planning. Planning should therefore be done upto the farmers' field, and land development measures such as land levelling and even bunding must be included.

6. Changes in the agricultural approach

Water is the most valuable resource for agriculture and hence it should be used wisely. Therefore, changes in emphasis on the use of water for agriculture will have to be accompanied by, and cannot be successfully implemented without, co-operation from the agricultural side, i.e. ultimately from the farmers' side and will require changes in the agriculturists' approach to irrigation. This leads to close integration of three main requirements in water use viz. (1) Combined use of water, other agricultural inputs such as good seed planting materials, fertilizers, plant-protection chemicals, production incentives and credit facilities, transport, storage and marketing facilities, etc. (2) Adjustments required in farm management practices, (3) Farm sizes in irrigation schemes according to managerial ability of the farmers.

Importance of operation and maintenance need hardly be emphasized. Lack of proper operation and maintenance prevents the famer from obtaining the full benefits and tends to make the farmer to lose interest in the project. Realising the importance of it, as an incentive to the farmer, the Government has decided to take over the full operation and maintenance and to relieve the farmer of this responsibility.

Another important change in the agricultural approach is the training of the farmer in modern methods of water management. The farmer must know how to apply water timely and quantitatively to obtain high crop yields ; he must know how to prepare his field and when to drain it from excess water ; and finally be must know how to conserve water and soil, the most valuable natural resources. Dissemination of such knowledge to the farmer in a form most acceptable and understandable to him is a tremendous task in communication. This gives rise to applied research and training which I propose to deal with later.

One of the significant and unsuccessful elements in the irrigation projects in the past was the selection of the type of settlers. Permit me here to quote from the Gal Oya Project Evaluation Committee.

> "The selection of the individual colonist from each feeder district proceeded in the paternalistic manner that has governed all such selections for decades. As a result, the colonist population is an amalgam of landless peasants with large families, those rendered homeless by natural disasters, fisher-folk in search of a new life, the odd undesirable exiled from his village and more diverse types. No attempt was made to judge the agricultural skill or other aptitudes necessary to establish a viable community. We have on the one hand the highly intensive cultivation of the colonists from Kegalle and Kotmale who come from areas where land is scarce and intensive cultivation is a tradition, and on the other hand the patchy fields of the Hambantota fisherfolk who became farmers only after they were transplanted into Gal Oya."

Attempts are now being made to select the right type of settler who has an aptitude for farming, capacity to do hard work, proficiency in skills other than farming, leadership, etc., and this has been adopted for the Uda Walawe Project.

7. Information needed for planning

I do not propose to deal with the variety of information needed for physical planning of a project such as climatic conditions, hydrology, hydrogeology, topographical information, agricultural soil surveys, foundation investigations, land resources, power resources, financial resources, etc. One factor which earlier planners did not take into consideration is the human resources. The best laid plans are futile without human resources to implement them.

For implementation of a project and to obtain the full benefits according to the plans, the designers and planners must take into consideration the number and the geographical distribution of the available labour population.

Need for Applied Research

In the preceding paragraphs I had indicated the need for communication with the farmer in the language he could well understand. This could easily be achieved through establishment of pilot projects to cover the whole project area, say, a pilot project for each tract with the farmers' participation. The training provided in pilot projects will not only educate the farmer in management and improved agricultural practices, but also the engineers, agriculturists, extension workers, irrigation water distributors, overseers and technical assistants. The training programmes should include more practical work and should not be laid out too ambitiously. These pilot projects will also enable to establish the basic data for project operation and management, to test the acceptability to farmers of irrigation practices and to determine the cadre for operation and agricultural activities.

At present, the Department of Agriculture in co-operation with the Irrigation and Land Commissioner's Departments has organized a scheme for the training of farmers through the establishment of pilot projects. However, it is felt that the desired results have not been sufficiently effective or widely distributed.

The mere idea of training afforded by these pilot projects cannot be expected to satisfy our ordinary farmers. They must be able to satisfy themselves that they can derive a reasonable profit from the improved methods that they are being encouraged to adopt. Every farmer must be given a guarantee of such a return for his endeavours. It is only then that he may be expected to deviate from the traditional inefficient practices he has been long accustomed to.

In order to achieve the above objective, the following procedure is suggested. The plots selected for a pilot scheme must be subjected to a detail soil survey to determine the water holding and fertility characteristics of the available soils. The entire cultivation procedure must be carefully programmed by drawing up a crop calendar for the whole growing season, which will indicate the dates for sowing, fertilizing, weed control, application of irrigation water, etc.

The quantity of water to be applied as well as the frequency of applications will depend on the physical properties of the soil and temperature, and consequently, on the moisture content determined from standard tests carried out from time to time.

The Agricultural Department could forecast the yield to be expected from a given crop to be grown on a pilot plot in relation to the available research information and this can be considered as the guaranteed yield from the plot.

The incentive for achieving high yields should be provided in the form of a special crop insurance scheme i.e. if the plot fails to produce the guaranteed yield obtainable through the adoption of new farming practices recommended by the extension services of the Agricultural Department, the Insurance Corporation should pay compensation to the farmer to the extent of the value of the shortfall from the target yield.

It would also be appropriate to reward in some way those farmers who may obtain yields in excess of the guaranteed yield. This will be an incentive for other farmers to follow the practices laid out in the pilot projects.

Such a guarantee will ensure that the farmers will be sufficiently motivated to adopt improved techniques, to become conversant with modern water conservation practices and to become acquainted with the correct use of fertilizers and agrochemicals, since there will be no fear of monetary loss.

The main objective in this form of guaranteed training is to impart the knowledge gathered from research and experiments to the farmer in a manner that is most readily acceptable to him.

Training

Training is a means to bring about continuous improvement in the quality of work performed by those engaged in the various activities. Different government departments are involved in various phases of planning and execution. Staff at different levels have to be engaged and therefore training at all levels is required to achieve full benefits from a scheme. For efficient management pre-service, in-service and follow-up training programmes are necessary. In order that young engineers, agriculturists and technicians, may have a sufficient knowledge of irrigation and agriculture, courses in irrigation and agriculture should be included in the curriculum of Engineering and Agricultural Faculties of the Universities and Technical Schools. Post-graduate courses in the field of irrigation, agriculture and water management are also helpful for the staff to have up-to-date knowledge of improved methods.

Technical assistants, engineering overseers, agricultural instructors, Extension Workers and other staff engaged in the activities of agricultural production have also to be trained. The main emphasis of training at this level will have to be placed on practical work and therefore should be connected with pilot projects. In the preparation of programmes for training, one principle that has to be observed is that training must be simple and on practical subjects and should not be laid out ambitiously. Training programmes may also be in the form of study circles, films and seminars.

As the farmer is the ultimate person responsible for producing full benefits from irrigation projects programmes in the form of pilot projects with farmer participation as described previously should be arranged to train the farmer in the modern concepts of irrigation and agriculture.

Conclusion

Irrigation water is very costly and therefore should be used to serve maximum returns in the shortest possible time. The importance of realizing the full benefits is felt more today than in the past specially considering the steps that are being taken by the

Government to achieve economic stability for Ceylon. This can only be realized if our planners understand the problems that confront us in the implementation of a project at all levels commencing from investigation and planning to production. I have in this address attempted to outline briefly some of the important problems that have inhibited the success of the schemes in the past and steps already taken and suggestions to overcome these problems in the future. All activities of planning, construction, research, training, community development, extension services, health, communication, education, etc. have to be integrated and oriented in such a way as to provide the financial, technical, material and organizational support to the farmer. All these have to be geared and oriented to a single objective giving support to the farmer in his enterprise. In conclusion I may say that planning should commence at "grass-roots level" to achieve the final goal of "full benefits."

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5. River Valleys Development Board, "Annual Report for 1966-67", Sept. 1968.
6. Government of Ceylon, Ministry of agriculture and Food, "Agricultural plans", First Report of the Ministry Planning Committee, 1958, pp. 33-37
7. op e t, (Ref. o. 3).

Table I

Acreage Provided with Irrigation Facilities—The Gal Oya Valley

Item/Year	50/51	51/52	52/53	53/54	54/55	55/56	56/57	57/58	58/59	59/60	60/61	61/62	62/63	63/64	64/65	65/66	66/67	*Total*
1. New Acreages brought under irrigation :																		
(*a*) Paddy	3,242	5,339	7,551	4,607	2,076	2,056	1,589	5,669	—	208	120	2,700	2,586	1,000	200	740	6,273	45,956
(*b*) Sugar Cane	—	—	—	—	—	55	226	723	1,382	849	1,294	1,300	271	2,000	1,200	900	2,064	12,264
(*c*) Other Crops (Tobacco)	—	—	—	15	50	81	276	205	70	176	338	10	—	—	—	—	—	1,221
2. Already cultivated land provided with irrigation facilities for the first time :																		
(*a*) Paddy	—	—	—	—	1,625	3,820	3,922	5,816	—	—	—	—	—	—	—	—	—	15,183
(*b*) Sugar Cane	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—		—
(*c*) Other Crops	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
3. Irrigable land provided with improved irrigation facilities	—	—	—	—	29,893	2,343	2,275	—	—	—	—	—	—	—	—	—	—	34,511
Total ..	3,242	5,339	7,551	4,622	33,644	8,355	8,288	12,413	1,452	1,233	1,752	4,010	2,857	3,000	1,400	1,640	8,337	109,135

Source : River Valleys Development Board, Annual Report for 1966/67.

Table II

Average Incomes and Sources of Income in Terms of Four Groups of Settlers (Rupees), 1956/66

Sampling Groups	*Tank Bed*	*Muslims*	*East Coast Tamils*	*Sinhalese*	*Average per Allottee*	*Percentage*
Number of Allottees	61	100	261	606	1,038	—
Paddy Maha	636.44	865.45	650.98	1,271.30	1,036	47.1
Paddy Yala	364.05	285.91	248.97	957.34	672	30.6
Tobacco	16.75	50.47	95.36	13.73	70	3.2
Livestock	15.74	28.01	27.78	53.76	41	1.9
Services	107.66	79.05	148.44	25.85	70	3.2
Other	42.15	10.86	19.46	29.01	32	1.5
Sub-Total	1,182.79	1,319.75	1,190.99	2,350.98	1,921	87.5
Products	4.02	80.16	11.40	12.22	19	0.8
Services	131.72	520.76	198.61	201.69	229	10.4
Rent	4.16	19.72	9.89	3.38	6	0.3
Other	3.93	115.00	16.67	8.95	22	1.0
Sub-total	143.84	735.65	236.58	226.25	276	12.5
Average Income	1,326.62	2,055.41	1,427.57	2,577.23	2,197	100.0

Source : River Valleys Development Board, Annual Report for 1966/67.

Table III

Percentage Distribution of Allottees in the Various Income Groups In Terms of Four Groups of Allottees

Income 1965/66 (Rupees)	*Tank Bed People*		*Tamil*		*Muslims*		*Sinhalese*		*Total*	
	Number of Allottees	*Percentage*	*Number of Allottees*	*Percentage*	*Number of Allottees*	*Percentage*	*Number of Allottees*	*Percentage*	*Number of Allottees*	*Percentage*
0 — 400	9	14.8	19	7.3	4	3.6	5	0.7	37	3.6
401 — 800	9	14.8	41	15.7	12	10.9	27	4.5	89	8.6
801 — 1200	15	24.6	60	23.0	16	14.5	47	7.8	138	13.3
1201 — 1600	12	19.7	47	18.0	16	14.5	83	13.7	158	15.2
1601 — 2000	6	9.8	37	14.2	14	12.7	84	13.9	141	13.6
2001 — 2400	4	6.6	28	10.7	19	17.3	83	13.7	134	12.9
2401 — 2800	3	4.9	12	4.6	9	8.2	50	8.3	74	7.1
2801 — 3200	1	1.6	5	1.9	6	5.6	62	10.2	74	7.1
3201 — 3600	1	1.6	3	1.1	2	1.8	54	8.9	60	5.8
3601 — 4000	—	—	4	1.5	4	3.6	26	4.3	34	3.3
4001 — 4400	—	—	2	0.8	—	—	28	4.6	30	2.9
4401 — 4800	—	—	—	—	3	2.8	18	3.0	21	2.0
4801 — 7201	—	—	3	1.1	3	2.8	28	4.6	34	3.3
7200 and Over	1	1.6	—	—	2	1.8	11	1.8	14	1.3
Total ..	61	—	261	—	110	—	606	—	1,038	100.0

Source : River Valleys Development Board, Annual Report for 1966/67.

Presidential Address*

SOME TRENDS IN SCIENCE EDUCATION AND SCIENTIFIC RESEARCH IN CEYLON

by

H. CRUSZ

University of Ceylon, Peradeniya

I am deeply grateful for the honour you have done me in having elected me President of the Natural Sciences Section of the CAAS.

I was in two minds when it came to selecting a theme for my Presidential Address. I was greatly inclined to reviewing a field of knowledge related to my own researches, but I have deferred to a large number of my colleagues who were of the opinion that our times call for some plain speaking on matters relating to science education and research in Ceylon.

I am comforted by the thought that Presidential Addresses of most Associations for the Advancement of Science have, instead of " reviewing fields of knowledge", started " raising wider questions of science in the country concerned, namely policy, utilisation of results of research, organisational problems and ethical questions in the context of science and society "(1).

In adopting a similar attitude, I am going to paint for you today a rather plain and straightforward picture on the subject of my address. In doing so I shall try my best to avoid the elongations of an El Greco or the deliberate distortions of a Picasso, or even the intellectualism of so-called Abstract Art. I shall " concretize " as far as possible. Once in a way, I shall even do what some abhor, namely " anecdotize ". One need not be apologetic about this, however, for according to the Oxford Dictionary anecdota simply mean " unpublished details of history ".

*delivered on 17th December, 1970

I shall therefore begin with such an anecdote. The British *Times Educational Supplement* of December 5, 1969, carried an advertisement from the Ministry of Overseas Development and the British Council, which read as follows :—

> " Tutors are required to help staff in-service teacher training courses for local teachers which are to be held in various centres in Africa, Asia, the Caribbean and the Mediterranean in summer 1970............
>
> CEYLON (i) Tutors for a course in science (Chemistry, Physics and Biology) at " Advanced Level "............ 4 weeks duration............
>
> Candidates must be Heads or Deputy Heads of Primary or Secondary Schools, Heads of Departments of Secondary Schools or Lecturers in Colleges of Education, Establishments of Further Education or University Schools of Education in the U.K."

This advertisement so intrigued a Ceylonese in the U.K. that he wrote to a high academic in Ceylon, expressing his surprise and concern and requesting some clarification as to what the project really meant. The implications were however quite clear. Ceylon has to depend on tutors from abroad for teaching her ' A-Level ' teachers how to teach, even with regard to subjects like biology, where one would expect not only a teacher, but more so a teacher of a teacher, to have first-hand acquaintance with local organisms and local environmental conditions and problems. In saying this I mean no disrespect whatsoever to those kind and brave people from Britain who have come to Ceylon in response to this call. I only ask them and you to join me in further considering this matter.

In view of this rather uncomplimentary state of affairs, we should examine the steps that have been taken so far to develop and improve science-education in Ceylon, and see whether we have been on the right track and what, if any, are the impediments to further progress in this direction.

Government's Science Teaching Development Programme—'Ordinary Level'

I do not think one could doubt for a moment that the Government of Ceylon's Education Department has initiated and carried out programmes of science teaching development, which have had an impact even on educational circles in other countries. In keeping with the urge everywhere, not only in developing countries, but in the developed ones as well, to rethink curricula in relation to the demands of a modern scientific, technological and democratic age, Ceylon too began planning her Science Development Programme as far back as 1957, with UNESCO assistance. A survey revealed that there were 3 levels of science teaching that needed attention, namely Grade 6-8 Level (11 + to 14 + age-group), Grade 9 & 10 Level or G.C.E. 'O-Level' (14 + to 16 + age-group) and Grade 11 & 12 Level or G.C.E. 'A-Level' (16 + to 19 + age-group) (2).

The thinking and the educational experimentation that went into the initial stages of this Programme, in relation to the first two Levels, have been recorded in the 1963 Report prepared for UNESCO by the Department of Education, Ceylon. Special mention must be made of over 19 Working Principles and Criteria which emerged from these studies and which were to be guide-lines for future work on Syllabuses of Instruction and Schemes of Work in science teaching at these levels. For example, it was decided that the schemes should contain "many common points of contact with the current schemes elsewhere in the world", due regard being paid to the Ceylon situation. By this was meant the new orientations such as reduction of informational content not directly essential to the establishment of important concepts and models, the increase of student involvement in scientific activity including open-ended experiments, the increase of skills in the quantitative aspects of investigation, and provision for periodic evaluation of the schemes. It was also cautioned that the new schemes of work should not demand a complete re-training of existing staff, although some re-orientation in methods and attitudes of teachers had to be achieved if there was going to be any change from the *status quo* in science teaching. In the specific Ceylon setting, it was also recommended that "teaching methods should involve the barest minimum of killing of animals and collection of killed material".

Perhaps one of the most important guide-lines was that the design of the schemes should be double-based, namely 1) on the logical development of the subject and 2) on the significance of the material from the point of view of its applicability and usefulness in everyday life.

Armed with such a valuable set of findings, the Department set about producing materials for school use in the ' O-Level ' Classes in Physics, Chemistry and Biology. This was done by the Department's own staff and the materials have been in use in schools since 1964. Revision in selected areas has been done by the Department's Biology Curriculum Team. It is on record that " when a national or public curriculum is to be revised a special committee is appointed for this purpose. This committee will be composed of the official of the Ministry, the members of the universities and experienced teachers" (2).

In spite of this, very little use has been made of the " members of the universities ". There has been no determined effort to use them as fully as possible and with as wide a coverage as possible from the point of view of specialists in all aspects of the subject. Soliciting the help of a few university people, generally on a personal basis, is hardly a way of tackling so vast and exacting a problem.

There is also the very real hazard of not having the right type of university teacher and researcher among the few who are used, if they are used at all, for curriculum writing and revision. This assumes special importance when it is viewed together with the observations made later on in this address, in regard to trends in scientific research in this country.

All in all, there is nothing like having a formidable body of competent biologists, drawn equally from the universities and from the schools, to write and revise a biology curriculum. This has been the tested experience of the world's best curriculum revision projects in biology, such as the Biological Sciences Curriculum Study (BSCS) of the U.S.A. (*see* Grobman, 1969) (3) and the Nuffield Project of Great Britain.

I am not competent enough to deal with the teaching materials in Physics, Chemistry and Mathematics. Even if I were, it would not add much to my argument. For, if it can be shown that one such scheme, for example the biology scheme, is deficient in several respects, then, even if the other schemes are admirable, there will already be an undesirable imbalance in science teaching at the 'O-Level'. One has to be careful about this in planning a course. Hulda Grobman's words (1966/69), written in another context, could be applied here too. "It may be", she says, "that one cannot expect student performance to reflect the new thrust in a biology course until there are parallel new thrusts in other curricula consistently throughout the school and college years" (4).

I would classify the deficiencies in the Education Department Schemes in Biology as follows :—

1) Errors and howlers that pass off for facts.
2) Pedagogically unrealistic treatment of certain teaching sequences.
3) Spelling out of outcomes, which could easily degenerate into dictation.
4) General imbalance in choice or omission of subject matter.
5) Lack of Ceylon data, despite the considerable amount of applied biology in the course.
6) Lack of correlated sample test-papers and guidance for teachers in evaluation techniques.

The strong points in the schemes, on the other hand, stem from the original aims and guide-lines, however much the actual schemes fall short of them. The very fact that new schemes were started at all is praiseworthy. The deficiencies would however appear to stem from one serious situation in the whole programme, namely the lack of expertise and the right type of personnel for producing at least satisfactory materials, let alone materials of a high quality.

Facts are the foundation of scientific work. Even in open-ended experiments, i.e., experiments where the results are not anticipated at the beginning of the exercise, one has to set about one's task, equipped with preliminary facts and assumptions. Unfortunately, the teacher's guides produced in at least one subject, biology, have so many errors and howlers, that one loses confidence in the accuracy and the authenticity of the material. Even in science, statements have to have some degree of credibility.

This problem is so acute that it led one educationalist (Jayasuriya, 1969) to quote, from " a single term's course guide of 56 pages ", eight selected passages which he described as " confusions and absurdities which mystify the young science graduate " (5).

Here are a few more examples from the same work (6) (italics mine) :—

(*a*) " The occurrence of changes in the form and structure of animals in the development *of an egg* to adult is known as metamorphosis ". (p.11).

(*b*) " Self-fertilisation is a sexual means of reproduction, but a regression from true sexual form, offering a lesser chance of variations or mixation but higher than in vegetative means ". (p.46).

(*c*) " In a large population there are as many individuals having one character as those having the opposite character ". (p. 48). In regard to this particular so-called " main teaching outcome ", W. H. Dowdeswell of Bath University and Nuffield Project made the following comment, with characteristic British understatement: " Meaning not clear ; surely this is not so ? " (7).

Here are some more from the Scheme for the First Year—Second & Third Terms (8) :—

(*a*) " Recall the enzyme ptylin. Similar enzymes are produced in the stomach and small *and large intestines* ". (p.36).

(*b*) " The importance of bacteria in the digestive systems of Termites can be mentioned. *No enzymes are effective in the digestion of cellulose.* Termites feed on cellulose. The cellulose is decomposed by the bacteria present in the digestive system. Hence the Termites would not be able to support themselves on cellulose but for the bacteria" (p. 53).

(*c*) " The incisors *as well as the molars* (of the rat) are continuously growing to replenish wastage in gnawing ". (p. 31).

It is relevant to refer to two answers that have been given to criticisms of these texts. First, that it is wrong to refer to the " English " version of the texts, when it is Swabasha that is being used in the schools. Secondly, that the texts are only " provisional " as has been clearly stated in the prefaces to the different schemes, where criticisms have been solicited.

The first is hardly an answer to our criticism. If at all, the chances are greater that Swabasha translations will be not any better, even worse, than the original " English " text, not necessarily from the point of view of language, but from the point of view of further distortion of factual material. With this would go the added disadvantage that the chances of rectifying errors and howlers will be much more remote, since Swabasha materials would be available to a far smaller population of competent judges. The errors could therefore thrive longer in such a situation.

That the texts are " provisional ", is no answer to a situation where immediate withdrawal or revision is called for by the very nature of the material purveyed. I shall refer to this again in the next section. Problems like this no doubt arose even in the BSCS programme, when, at one point, " the discussions were rather heated " and the Steering Committee members had to be reminded that they were " not criticising finished books " but " trying to improve embryo books " (Grobman, 1969) (3). I do not think that the local counterparts deserve to be called even " embryo books ".

CAAS School Biology Project—' Ordinary Level '

It must be said, to the credit of those Education Department officials who were most involved in policy making, that they themselves probably felt a certain uneasiness at their own biology materials. This might account for the readiness with which their support was given for the inauguration in 1964, and the continuance, of the CAAS School Biology Project (SBP) and also for the fact that all the " Syllabuses of Instruction and Schemes of Work in Biology for G.C.E. ' O-Level ' Classes " (6, 8) carried an announcement to the effect that the CAAS has commenced a School Biology Project, the aim of which was to " improve the teaching of Biology at the G.C.E. Ordinary Level in Ceylon Schools ". There was also a somewhat puzzling statement to the effect that " the School Biology Project welcomes any criticisms of, and improvements to *this scheme* ", i.e. the Education Department's Scheme.

This raises an important issue. The criticisms to the Education Department Scheme were to be directed not to that Department, but to the SBP. That would have been understandable, if the SBP was going to supplant the Education Department's project. Actually, the SBP is a parallel project. One would have therefore expected the Education Department itself to have been the sole recipient of criticisms of its own schemes. In fact, in at least one text (9) it is stated that such criticisms had indeed been received during the preparation of these " provisional schemes", from members of the University of Ceylon, Training College Staffs and Inspectorate, but that "the nature of the task prevented the incorporation of many of the useful suggestions that were made." However, a further notice added " that the co-operation of teachers in teaching these syllabuses and their assistance in such revision is earnestly solicited."

I shall not go into the details of the formation and work of the SBP. Most of you are familiar with them, as the Project is a CAAS undertaking, and they are in any case on published record (CAAS Annual Reports since 1964, and Crusz, 1966/69 (10) and Basnayake, 1969 (11)). It is enough merely to say that the thinking and work of the SBP have been enthusiastically appraised in educational circles both here and abroad. Grobman (1969) in his significant book *The Changing Classroom* writes of the " numerous materials " of the SBP " which are quite original in concept and take advantage of already published items, including those produced by the BSCS, the Philippine adaptation of the BSCS Green Version and the Nuffield Foundation of Great Britain. One of the features of the Ceylonese work is a series of problems similar to *Invitations to Inquiry* based solely on biological data from Ceylon. The next step in the work of the Ceylonese project is to translate some of the experimental materials into Sinhalese and Tamil for trial use with students under local conditions" (3).

In fact, this last step has already been taken, with some 23 classes in 16 schools in the Kandy district, and valuable feed-back has been obtained. The first examination based on the SBP coarse was held in December 1969. SBP questions formed part of the

G.C.E. (O-Level) paper for SBP candidates sitting the Government Examination. These questions were set by SBP personnel and it was a most progressive step in that accommodation was made in a public examination for candidates taught in a non-governmental curriculum trial.

In all its work of programming, writing, teaching, examining and evaluating, the SBP has relied on the co-operation of several teams comprising school and university biologists in almost equal numbers. In fact in 1968 the National Council for Higher Education, on a request made by the CAAS, recommended to all the universities that "(a) members of the academic staff of the universities be given official permission to continue to assist in the work of the School Biology Project, and (b) Some recognition be given to those who spend time and effort on such work".

In spite of this, there are several shortcomings even in the SBP schemes. Some of these drawbacks are shared with the Departmental schemes. Let us have a look at those that have been so far recognized.

1) The SBP has also emphasized the main ideas, but these have to be elicited in the course of the encounter in class between teacher and pupils. The outcomes are not spelled out as in the Departmental Schemes, so that dictation of material is not possible in the SBP course.

2) Like the Departmental course, the SBP course could lead to a strait-jacketing of teaching. There should be more scope for alternative approaches, on the teachers' own initiative.

3) Neither course has dealt adequately with project work. It is hoped that ways and means of doing this will emerge from the Third Biennial Conference of the Asian Association for Biology Education (AABE), which is scheduled to begin in Manila on December 28, 1970. The theme of that Conference will be "Research Projects in School Biology Teaching", a theme suggested by Ceylon's SBP. Some of the project papers to be presented by Ceylonese school-teachers at this Conference are interesting: (1)

" 'Green' Bean and 'Butter' Bean—Varieties or Species " by Miss P. Marandawela of Menikdiwela Maha Vidyalaya; (ii) " Supporting Function of Collenchyma as seen in the Petiole of *Typhonium roxburghii* " by Mrs. I. Eriyagama of Girls' High School, Kandy ; (iii) " Colour Changes in the Petals of *Hibiscus mutabilis* " by Mrs. G. J. Hoole of Hillwood College, Kandy; (iv) "Age of Menarche in School-girls in Kandy, Ceylon " by Miss P. Dissanayake of Maha Maya Girls' School, Kandy; (v) " Some Observations on the Breeding Habits of the Ceylon House Sparrow " by Mr. C. J. S. Daniel of Trinity College, Kandy and (vi) "The Amount of Water Given out from Leaves of Different Ages " by Mr. A. Weerasinghe of Trinity College, Kandy.

4) Mathematics has played too small a part in both courses. This is a serious drawback, if Mathematics is at the very base of scientific investigation.

5) Neither course has placed enough emphasis on field work and ecology and in the acquisition of a cultivated awareness of one's environment for its own sake. The teaching of nature conservation might become difficult in such a situation, without the necessary emotional build-up which science teaching can achieve. In this connection it should also be noted that in both courses non-verbal learning has been almost totally neglected. Aldous Huxley's *Island* (1962) which provided a take-off point for a previous essay on Science Education (Basnayake & Crusz, 1966/69) (12) speaks of one of the prescriptions for sound education in the utopian island of Pala, namely " Discouraging children from taking words too seriously ......But what you can get out of a book is never *it*. At bottom, all of you are still Platonists. You worship the word and abhor matter." (13).

6) Lastly, what has been done to foster creativity ? We are preoccupied with, and catering for, the average pupil. This can be dangerous. The problem was recognised by both the great curriculum projects, BSCS and Nuffield, and they have tried to solve it in their own different ways.

'Advanced Level' Teaching and Examinations

I have been so far trying only to prepare the way and lead you up to what I would like to call, without any exaggeration, the debacle of the G.C.E. (A-Level) teaching and examinations. You would remember that I started with an anecdote concerning teachers from the U.K. for training 'Advanced-Level' science teachers in Ceylon. We shall return to that theme once again.

For many years the General Certificate of Education (Advanced Level) Examination, the Higher School Certificate Examination and the University of Ceylon's Preliminary Examination were different things. From 1952 to 1963-68 Ceylonese candidates sat the G.C.E. (A.L.) Examination conducted by the University of London. The Practical Tests for this Examination were set by examiners in London and conducted and sometimes even marked, on instructions from London, by local examiners from the University of Ceylon.

The University of Ceylon's Preliminary Examination was held right up to 1963. The H.S.C. Certificate was given by the Education Department on the performance of candidates at the University Preliminary Examination.

With the decision to do away with the London Examinations and hold a local G.C.E. (A.L.) Examination, the Commissioner of Examinations took the responsibility for conducting the A.L. Examination and the Controlling Chief Examiners were Heads of Departments of the University, while a good proportion of the Assistant Examiners, at least in the science subjects, were also drawn from the University. The University's Faculty of Science and Senate insisted on University involvement at least to this extent, as long as the A-Level Examination was going to function as a University Entrance Examination as well.

The Preliminary/H.S.C. Examination was held for the last time in 1963 and the Ceylon A.L. Examination came to function in and after 1964 not only for purposes of a General Certificate of Education but also as the University Entrance Examination. Indeed, the University Preliminary Examination syllabuses, at least in the science subjects, continued to be used for the new A.L.

Examination and even the number of papers to be taken at the Examination remained the same. From 1965, two papers were set in each subject, but still on the rather limited Preliminary Examination syllabuses. In 1967, the syllabuses were also changed to make them conform to A.L. standards in the U.K.

The use of the A.L. Examination as a University Entrance Examination resulted in several misconceptions in the minds of everybody regarding the true nature of an A.L. Examination as against a selective examination for University purposes. The Ceylon A.L. Examination was almost foisted on the country with no adequate planning and preparation. Sound and concrete recommendations made by the Controlling Chief Examiners for setting up a qualified and representative board to deal with the conduct of the Examination in a uniform and satisfactory manner were largely ignored, and the authorities went on regardless for the last seven years.

The University personnel tried to do their best in the circumstances. A very early inclination, on the part of some at least of the Science Examiners, not to have anything to do with the conduct of the Examination, faded away owing to considerations of the importance of University involvement, whatever the circumstances, as long as the Examination was being used for University Entrance purposes as well. In the G.C.E. (A.L.) work, as in the G.C.E. (O.L.), there was a definite tendency for certain sections of the education authorities to try to go it alone without University help and involvement. The only way the universities were involved was when the heads and other senior teachers in the University science departments were invited to occasional "Conferences" generally to get University help in implementing decisions already taken by the Government officials. The dons mostly revolted at such an attitude. One could have condoned this attitude on the part of the authorities, if there were able and adequate personnel among them to do the job. But it was obvious that that was not the case.

The gulf between the University of Ceylon and the other newly established universities on the one hand, and the Government Education authorities on the other, was widening more and more. This is now part of the political and educational history of our country. Ministers of Education came and went, but the men who really wanted power at the expense of educational standards and the intellectual future of our children remained. The technique adopted was to mess up as completely as possible and then blame it all on the universities.

The science departments of the University of Ceylon and the CAAS School Biology Project, which was closely linked with them, began thinking seriously about the A.L. situation. This led in February 1967 to the Director of the SBP sending a memorandum on the subject to the education authorities. It was " An outline of a proposal for curriculum revision in biology at G.C.E. (A.L.) and General Science Qualifying Level (first year in University biology)". In the course of this memorandum the SBP Director states " It seems a pity that no studies are being done of this curious transitional phase in the history of science education in Ceylon. More concrete evidence that A.L. biology curricula will inevitably undergo revision includes the fact that the Departments of Botany and of Zoology in the University of Ceylon, Peradeniya, have already prepared tentative drafts of new A.L. syllabuses in Botany and Zoology (Appendix). There have been meetings of University A.L. Examiners to consider overhauling the A.L. Examination. These are signs of a movement towards A.L. curriculum revision, and while the causes of such a movement are likely to be multiple and complex rather than single and simple, it is interesting to note that the movement is most marked in biology rather than in chemistry and in physics " (14). The SBP Director goes on to discuss the impact of curriculum revisions in A.L. and University biology in other countries and he reads signs of dissatisfaction with the Ceylon A.L. and G.S.Q. Examinations even among University Examiners themselves. He rounds off the memorandum with a plan for curriculum development, including its financial implications. It was hoped that the fiscal support would come from the Asia Foundation or other donors, through the Ministry of Education. The memorandum was fully discussed and well received at a SBP meeting at which there was a very representative body of biologists from the University of Ceylon. Even a prototype question paper was prepared.

The Education Ministry did not appear to be interested, and so nothing came of all this. The prototype question paper itself is still in cold storage. Very soon however we heard of the Education Ministry's utilising U.K. aid for proceeding with their in-service institutes for A.L. teachers during the holidays. This entailed regular visits of foreign personnel for the purpose of teaching our school science teachers the art of teaching subjects like Physics, Chemistry and even Biology at A-Level. Very curiously our own University personnel were consulted only when the organisers were up against difficulties in setting up experiments etc., in the context of Ceylon's own environment. It was, generally speaking, a niggardly treatment all round of our University men, who have been all the time most keen and anxious to step into an area which most concerned them and their future students.

The " last scene of all that ends this strange eventful history" seems to be just round the corner.

A notice dated August 19, 1970, appeared in the Government Gazette and daily press informing the public that at the A.L. Examination in and after 1971, there will be two question papers in each of the subjects Physics, Chemistry, Botany and Zoology, the first paper consisting of approximately 100 test-items of fixed response multiple-choice type and the second paper of questions involving short-answer responses and structured essay-type questions. All practical tests would be abolished. Instead, the Director-General of Education would be taking steps to establish a pattern of continuous assessment of the practical work done by the students as part of their day-to-day study in the classes, i.e. in at least about 200 classes throughout the island. The practical work would be assessed systematically as directed by the Director-General and the Commissioner of Examinations. The eligibility for and entry to the Examination would be determined by this continuous assessment of practical work. Private candidates, on the other hand, would have to apply to the Commissioner, for the terms governing their eligibility.

The implications of this amount to there now being about 200 centres (= 200 AL schools), at least 200 examiners for practical work (= 200 biology teachers who will be doing the assessment) and the Examination (=continuous assessment) will be spread over a couple of years. In other words there will be a "complexification" of the system with the resultant hazards, the greatest of all the hazards being the problem of bringing about uniformity in standards and adjudication, and the problem of disciplinary control over such a wide variety of both students and teachers, the students ultimately demanding that they be passed despite bad performances.

The press notification referred to was made by the Commissioner of Examinations on a ministerial directive to him to change the scheme of the Examination in these 4 science subjects and to implement it from 1971.

After the press notification appeared, a letter went out to the Professors of Physics, Chemistry, Botany and Zoology of all the four universities, announcing the ministerial directive and inviting them to a meeting to "discuss this directive". The agenda for the meeting, however, listed only (a) The presentation of the Minister's directive (b) Discussion regarding implementation of the scheme and preparation of prototype question papers and (c) Revision of the syllabus for the 1972 examination.

In other words, a scheme was being foisted on the country without prior consultation with the universities and the universities were being asked more or less to conform or get out.

A Deputy Director-General of Education monopolised the discussion as far as the Government was concerned, and the mimeographed document he distributed before he began his monologue is a masterpiece of authoritarianism and bombast. No wonder the document bears the superscription "strictly confidential". Since I may not quote from such a document, I can only give you an indirect glimpse of it by quoting a passage from Lionel Trilling's *The Liberal Imagination* :—

> "A specter haunts our culture. It is that people will eventually be unable to say 'they fell in love and married' let alone understand the language of *Romeo and Juliet*, but will as a matter of course say, 'their libidinal impulses being reciprocal, they activated their individual erotic drives and integrated them within the same frame of reference'".

No wonder the communication gap between the teaching profession and the education bureaucracy is for ever widening, instead of closing.

The university professors, to a man, reacted strongly, to say the least, against this deplorable document as well as against the whole tone and manner in which they were being invited to fit into a predetermined plan. They were asked to consider ways of implementing the Examination design and not to review the design. The reviewing was to be done over the years, with feed-back from the total populations of Examination candidates or from 'suitable stratified random samples'.

This brings us to the subject of statistics. Colombo's Professor Emeritus of Physics, an alumnus of the Cavendish Laboratory at Cambridge, has already warned that " statistics is a tricky subject and ought to be handled only by experts in the subject and not by amateurs " (15). He wrote this in connection with the recent admissions to the universities on the 1969 AL Examination results.

An illustration of the danger of misinterpreting statistics is the fantastic suggestion made sometime ago that the lack of correlation in candidates' performance between Theory and Practical at examinations, pointed to something wrong in the examination system. When this very question was raised at the meeting, one of the professors pithily commented that if he wanted to recruit a person who could ride a bicycle, he would get that person to demonstrate his bicycle-riding ability by actually riding a bicycle, not by writing about a bicycle. Theory and Practical are different disciplines. If there were correlation between them a Theory paper alone would do for testing Practical ability.

All this concern with numbers, with statistics, is a laudable thing if done with competence rather than authoritarianism. It was a religious dignitary, of all people, who once remarked to me that only competence should be allowed to question and correct competence, not authority. Such mathematical tools as statistics and standardisation, used in educational practice, should not only be done by competent persons, but also be open to scrutiny by competent persons.

The recent admissions to the universities, again foisted by the authorities on bewildered and unwilling universities, are a case in point. The Government Department of Information has, however, issued a statement (16), clarifying the basis for the 1970 University admissions. Let us say at once that it is a very welcome statement, setting out the position fairly and squarely. The aims are most laudable. We ourselves have had considerable experience now with students from the rural areas. We have had the pleasure of seeing many of them flower in our institutions and have endeavoured at every turn to detect and remove any handicaps they encountered, especially those due to circumstances beyond their control. We have viewed with considerable alarm the great dearth of Sinhala Science Teachers and the poor standards and facilities obtaining in the rural schools. We acknowledge wholeheartedly that something had to be done and that the remedy, to begin with, lay in the hands of the most competent authority, namely the Ministry of Education. Let us see if there has been justice and equity. Here are the admission figures released by the Government Department of Information :—

		Number admitted	*Minimum Total Mark for Admission*
Engineering—Peradeniya	Sinhala	86	227
	Tamil	60	250
Engineering—Katubedde	Sinhala	60	212
	Tamil	53	232
Medicine—Peradeniya & Colombo	Sinhala	137	229
	Tamil	103	250
Dentistry—Peradeniya & Colombo	Sinhala	17	
	Tamil	24	
Agriculture—Peradeniya	Sinhala	25	
	Tamil	17	
Veterinary Science—Peradeniya	Sinhala	15	
	Tamil	5	
Biological Sciences—All 4 Universities	Sinhala	111	175
	Tamil	41	181
Physical Sciences—All 4 Universities	Sinhala	178	183
	Tamil	92	204
Architecture	Sinhala	16	180
	Tamil	28	194

(See also: Fig. 1 showing admissions to the Science Faculty, University of Ceylon, Peradeniya.)

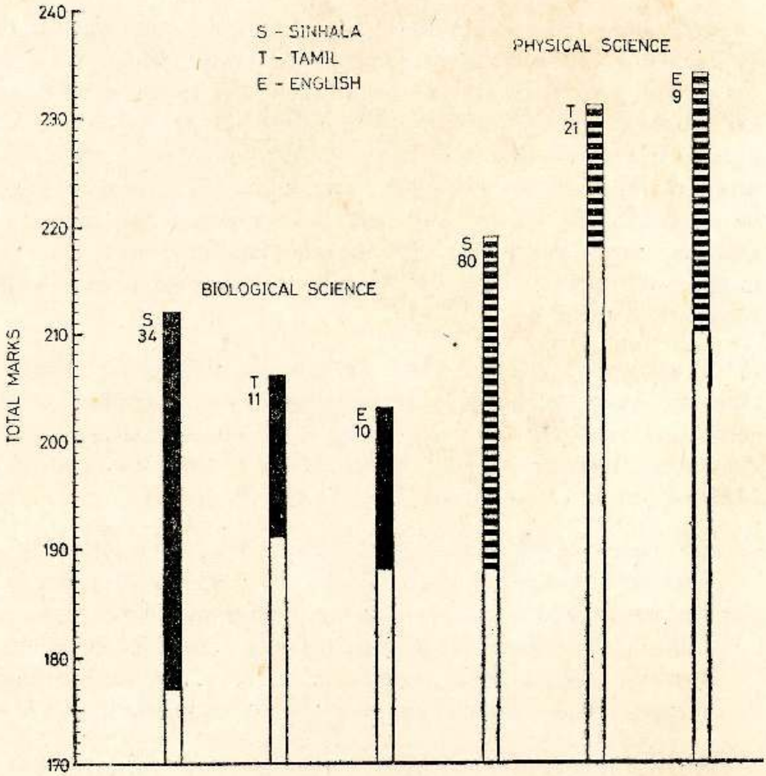

FIG. 1. Diagram showing admissions in 1970 to the Faculty of Science, University of Ceylon, on the basis of the total marks scored by candidates at the G.C.E. (Advanced Level) Examination of December 1969. The figures below the letters S, T and E indicate the numbers admitted in the respective language streams.

One thing appears to be certain about the selections made by the Ministry. The actual marks obtained by candidates remain the same and have not been tampered with. That is praiseworthy. But we find that the admission mark for one racial group is consistently lower than that for the other racial group. The question arises then as to why those many students of one racial group, who obtained marks between these two levels, have been rejected in favour of the other racial group. This is discrimination pure and simple.

It is a lack of justice and equity. It undermines all confidence in the authorities and even in the sense of worthwhileness in attempting to do well at an examination.

There also arises a subsidiary, but important, question. It is true that the marks have not been tampered with, which is all to the good. That being so, one would really like to know whether candidates from the rural schools have yet had a fair chance as against their counterparts in the so-called big schools. Nothing much of the kind seems to have happened. The rural schools have hardly been helped. All that has happened for certain is that one racial group has been discriminated against. Only a method of standardisation, on sound and accepted lines, could solve this problem.

It is also well to remember that we have got to be just and equitable, not simply to linguistic or racial groups as a whole, but to students as individual human beings. We should write in our institutions, in letters of gold, words similar to those of James A. Michener in his recent book *The Quality of Life:*—

> " I am not for Negro rights because I love the Negro but because I love all citizens. I love the grand possibilities of this nation and do not wish to see them diminish because we fail to utilize one of our greatest resources, the abilities of our twenty-five million black people. . . . . We are cheating ourselves when we cheat any segment of our population " (17)

I would add, not only any segment, but also any single individual, of our population.

Some Trends in Scientific Research

You would think that what I have to say now has hardly any bearing on what I have already said. I mean to keep you guessing, however, to fire your imagination at least by the time I have done. I will be as brief as possible since the subject is rather embarrassing. In the course of my remarks I shall have to cite particular instances to illustrate my points. But unlike as in the previous sections I will not be able, for obvious reasons, to refer to names of authors and titles of documents. Rest assured, however, that the documents are in my safe keeping.

I want also to emphasize that I will firmly avoid any personal invective. Wherever possible I will use language in such a way as to obscure as completely as possible the identity of persons. Although it must be said that in our community, the community of scientists, we should welcome, rather than object to, lambastings for academic lapses. Despite J. B. S. Haldane's opinion that " in science, efficiency is more important than courtesy " (18), I shall try to be as courteous as possible.

We have been witnessing here in Ceylon, within the last 10 years at least, a rather deplorable academic rat-race, particularly among persons by all accounts well qualified in the sciences. This has been brought on mainly by the untimely multiplication of science faculties, without adequate scientific man-power to support them. There is no sign that this rat-race would not go on unabated. We probably need more universities, but we simply do not have the wherewithal to multiply science faculties at the rate we have been doing.

In any case, let us be warned about the type of academic man we are going to have at the helm of affairs in our places of scientific work. It is too well known that in university science departments one is particularly concerned about providing students with the basic equipment in knowledge, techniques and attitudes for the appreciation and practice of science in the country. If our teaching staffs, in their researches and other scientific endeavours, are themselves found wanting in the very things they are obliged to teach, the position is bleak indeed, because education is a hereditary process, " educational backwardness is self-perpetuating " (Jennings, 1944) (19).

I would now make concrete what I have hitherto only hinted at. I will give you only a few examples in order to illustrate the phenomenon, because my time is limited. It would make a very interesting study to estimate the number of significant and inexcusable lapses shown by so-called academics who are running in the race for position and status at the cost of the more important qualities of academic and scientific integrity, not to speak of excellence. This is not to say that we are altogether lacking in persons having the latter qualities. The danger is they are too few and far between, to support adequately and influence the academic structure in a university.

Let us consider the following cases :—

(*a*) It was necessary in a certain set of experiments to maintain the pH at a definite level. This was done by the researcher, who had already had several years of post-graduate training abroad and a Ph.D., by merely adding HCl or NaOH to the unbuffered medium. He had no use for buffers to maintain pH for the rather prolonged periods of his experiments. To his credit, however, he had the honesty to describe in his manuscript his method of maintaining pH. We might well have called it " So-and-So's Method " if the manuscript had been finally published. Even a tenth grader in our schools would have known better.

(*b*) It was required to test the effect of a certain substance on an organism. The substance was used as a solution in alcohol and the organism apparently registered a sharp reaction to it. But one was at a loss to know how the organism would have behaved under the influence of the alcohol alone, without the other substance. The whole idea of a control experiment missed the mind of the investigator, who was a post-doctoral researcher.

(*c*) What would one think of an investigator, who in his or her hurry to record seasonal fluctuations of a particular organism or changes in species composition of a habitat, in relation to temperature changes, rushes into print, with the help of a willing publisher, with data collected for only one day and that too not for 24 hours. That person simply did not have the patience to do at least one replication, let alone a few replications, in this easily accessible spot. He or she probably feared that in that case the scientific world would have been kept waiting far too long to receive the brilliant findings. That investigator too was equipped with a Ph.D. degree.

(*d*) Ecological and physiological work and experiments often require even the most elementary statistical treatment.

It has been truly surprising to find raw numerical data lying untreated, and sometimes even uncommented on, although they were admirably suited in both quality and quantity to statistical treatment and comment. The high-point, however, in the use of statistics was reached when one young post-graduate researcher, supervised by a doyen in the field, calculated a standard deviation from only two readings available to him. A British colleague of mine who happened to see this in the manuscript he read, remarked, with characteristic understatement, " It is unrealistic to do so ".

I have given you only a glimpse, a sample, of the many cases I have come across of the lack, not of the imaginative leaps that go to make the first-class scientist, but of a true appreciation of the most elementary principles of scientific methodology and the ability to apply them and teach them, qualities fundamental to any researcher and teaching scientist, even if he or she does not belong to the charmed circle of the brilliant ones. Nor is this all. We have detected in recent times cases strongly suggestive of plagiarism, which have been of deep concern not only to responsible people in this country, but also to scientists abroad.

It is in this context that we have to examine the words of the Hon. Pieter Keuneman, Minister of Housing and Construction, in his address on the occasion of the opening of this 26th Session of our Association. " With all due respect " he said, " to the genuinely creative efforts at fundamental research, I think we must face the fact that, by and large, we have neither the need nor the financial or technical capacity to compete in this sphere. Such research work of a fundamental nature as we can afford to undertake should provide a take-off base for research projects of economic importance to our country and its people ". The problem is: could we provide even a take-off base under the conditions prevailing in our places of scientific training ?

We have to find quick remedies for this state of affairs. There has to be an insistence on rigorous standards in scientific research and publications. We have already begun to be much more exacting in refereeing for our journals of Science, and our panels of referees are also becoming more and more international. More than all this, we must not waver from the path of criticism. We must cultivate, in our scientific and other academic circles, the art of giving as much as taking criticism, whenever academic standards are at stake. This is part and parcel of the scientific process whether it be in education or in research. " The pre-occupation of academic people " says Professor Michael Polanyi, " with assessing each others' merits may seem petty, but it is indispensable for the maintenance of scientific standards. For these standards cannot be explicitly specified, and can be upheld, therefore, only by the intuitive connoisseurship that traditionally permeates the scientific community. To this extent a university must be an ivory tower. And this is not due to snobbery or lack of social conscience; it simply represents the necessary condition for cultivating science effectively " (20).

Here I cannot help thinking that the traditional charm and politeness of us Ceylonese could often be a stumbling block to our scientific progress. For, in Science, as Haldane has remarked, efficiency is more important than courtesy.

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SECTION E—PHYSICAL SCIENCES

Presidential Address

THE CHANGING FACE OF NATURAL PRODUCTS RESEARCH

by

L. B. DE SILVA

Natural products chemistry is essentially a branch of organic chemistry, itself one of the most remarkable of all the sciences in that it permeates practically every material aspect of modern civilization. Organic chemistry if the bridge between physical and biological sciences and it is perhaps the biggest of the sciences in the sense that this field attracts the largest group of adherents. It is remarkable that this whole edifice of modern organic chemistry rests on three basic concepts first propounded in the latter part of the last century.

1. The concept of fixed combining power of valence due to Frankland
2. Kekule—Couper theory of the tetravalency of the carbon atom and the capacity of the carbon atoms to join together into chains and rings
3. Vant Hoff-Le Bel tetrahedral carbon atom which gave rise to stereo-chemistry.

All these concepts have been purely empirical, but the foundation on which the whole science had been built had stood the test of time. There have been advances in theory but these advances have essentially been refinements giving more precise meaning, but have in no way upset the essential validity of these three propositions. This cannot be said of many other sciences.

The original impetus to natural products chemistry came from medicine and the use of natural drugs in medicine. The purely animal product cholesterol was isolated and described by Poulletier in 1780 and already in the eighteenth century what is called scientific medicine was being established. In 1785 the English physician Withering had introduced digitalis (purple foxglove) as a therapeutic agent for dropsy, the knowledge of the efficacy of the cinchona bark in malaria had been brought to Europe by the Spaniards. First the pharmacists and the then chemists began to busy themselves in the extraction and purification of the natural drugs known to be a of some value, and to study their chemistry. This turned out to be far from easy task and indeed the decision to put all such things into a separate section of science called organic chemistry was little more than a confession that natural products were different from and much more complicated at that from purely inorganic substances. The study of the natural products was far too difficult a task at that time and very little progress in natural products chemistry was made in the nineteenth century ; what little progress that was achieved took place in the last two decades of the nineteenth century. It became quite clear that no progress in natural products research could be made till a lot more was known about the carbon chemistry in the theoretical and practical fields. First the general theory of organic chemistry was developed and then the experimental techniques necessary for structural elucidation and synthesis were refined.

Round about the beginning of the twentieth century natural products chemistry suddenly blossomed out. One of the principal reasons was the apearance on the scientific scene of the scientific genius of Perkin, Willstäter and Fisher, just to mention three of them. Then the foundation of organic chemistry had been laid and necessary experimental techniques had been developed. Along with these there was the support of a new organic chemical industry. The impetus at this time was for the synthesis of natural products which might have all the virtues of the natural products whilst at the same time free of the inherent defects, as in the case of indigo.

It was at this time that Perkin and Wallach worked out the broad features of the chemistry of essential oils ; that the monumental work of Willstäter on chlorophyll and on the nature of enzymes was carried out ; that Emil Fisher made his brilliant investigations in the field of proteins and carbohydrates. Perkin and his equally brilliant students Thorpe, Simonsen, and Robinson added vastly to our knowledge in terpenes, colouring matters, alkaloids and carbohydrates ; that Windaus made significant contributions in the sterols and bile acids ; and finally Hans Fisher carried out his monumental work on porphyrin pigments.

At about this time it was evident that a limit in natural products research had been reached with the experimental techniques available. Willstätter's work on chlorophyll ran into difficulties and Fisher was halted in his protein work. Further progress had to await the refinements in experimental techniques. The first major advance came through the development of accurate and reliable microanalytical methods by Pregl which effectively cut down the amounts of valuable and scarce material needed for an analysis. Next came the introduction of adsorption chromatography, first by absorption on alumina columns. Chromatography was first developed by the Polish botanist Tswett but its use to organic chemists had to remain unknown till it was adopted by Kuhn and Brockman. This made possible the separation of closely related compounds where chemical methods were useless. The classical example of the use of chromatography is in the separation of leaf colouring matter into two yellow components carotene and xanthophyll and the two green components 'chlorophyll a' and 'chlorophyll b. Soon the column chromatography developed into a standard procedure and modern chemistry is now unthinkable without it.

All techniques of chromatography are based on a simple principle. They involve a moving system (liquid or gas) which is in equilibrium with a stationary phase. These phases were designed so that the mixture to be separated will be distributed between these two. When the stationary phase is a solid and the forces involved are adsorptive in nature, the technique is called *adsorption chromatography*. When the stationary phase is a liquid or liquid held on some support, the chromatorgraphy is called *partition chromatography*. Column chromatography with alumina which involves a relatively nonpolar moving phase is primarily an adsorption technique. On the other hand, the much more versatile silica gel which acts as a support for a liquid is *partition chromatography ;* this was, first introduced by Martin and Synge. The counter-current distribution of Graig may not strictly be defined as chromatography, but it is a partition technique adapted for preparative purposes.

Chemists have always been plagued with two important problems. How could you say that a given compound is pure ? Conversely how many components are there in a given plant extract ? The earlier chemists performed phenomenal feats by fractional distillation and fractional crystallisation in trying to solve this problem but a real answer to the problems posed, was supplied by Consden, Gorden and Martin by the development of paper chromatography. The method was fantastically successful and was rapidly adopted in every laboratory. The biggest advantage was the extreme simplicity of the method and the inexpensive equipment required. Paper chromatography found its first successful application in the separation of amino acids. Since paper chromatography is a partition technique with the stationary liquid phase held on filter paper, it works best with polar developers and small amounts of polar substances, and the temperature is critical.

The next diagnostic technique of chromatography is the *gas-chromatography*. This could either be an adsorption chromatography (G S C) as pioneered by Turner, Claesson and Cremer or partition chromatography as suggested by Martin and Synge and successfully introduced by James and Martin. The greatest advantage of G L C is the almost unbelievable degree of resolution with volatile oils and that the method can be used for quantitative estimations. One big disadvantage is the high cost of GLC equipment and its complexity and that the components to be separated should have some vapour pressure or be converted to compounds with vapour pressure at the working temperatures.

The greatest advance in this field has been the development of *thin-layer chromatography, TLC*. In 1938 two Russians Izmailov and Shraiber described the use of thin layers in the separation of plant extracts ; yet a period of twenty years had to elapse before the full significance of the technique was appreciated by the chemist and the biochemist. Though the progress is the result of the combined efforts of a number of investigators, yet it was Stahl who was mainly responsible for turning out standard equipment for the preparation of thin layers. TLC not only combines the advantages of paper and column chromatography but in certain respects is superior to either of them.

(i) It can be used for diagnostic, preparative and quantitative estimations.

(ii) It is much more sensitive and requires very little material.

(iii) It is very rapid, the amount of time taken varies from 15 to 60 minutes:

(iv) Corrosive reagents like concentrated : H_2SO_4 can be used as a spraying agent.

In many laboratories TLC is used as a standard purity check but it must be remembered that it can provide negative evidence of purity viz. that the material does not separate into components when chromatographed over certain substrates in certain solvents. The greater the number of combinations of substrate and solvent which the material fails to separate the stronger is the evidence for its purity. The speed of TLC can be exploited in following separations carried out by other methods e.g. multiple fractional extraction and column chromatography.

Two other techniques that find extensive use in natural products research, especially when dealing with macromolecules are *ion-exchange chromatography* and *electrophoresis*. Other methods of separation include molecular distillation, dialysis, sublimation, freeze drying, diffusion and ultracentrifugation. Today these new techniques are so widespread that at the isolation stage one could hardly conceive of a natural products laboratory that does not employ elution, partition, paper, ion-exchange and gas liquid chromatography. The development and the application of these new techniques have made possible the exact study of complex natural macromolecules like tannins, polysaccharides, proteins and nucleic acids. In other words the new experimental techniques have revolutionized the isolation procedures.

At the next stage i.e. structure elucidation, perhaps an even greater impact has been made by the physical methods which became available from the nineteen forties. These physical methods were invariably discovered by physicists and physical chemists, but their extensive application to organic chemistry was usually accomplished by a semi-empirical approach in which a great number of organic compounds were examined and then the chemical structure and the particular physical property under discussion were correlated. Chronologically UV spectroscopy was followed by IR measurements, then NMR studies and about the same time mass spectrometry and finally ORD.

U. V. ABSORPTION SPECTRA

It has been common knowledge that colour or absorption of light in the visible region (4,000 — 8,000A°) was associated with certain unsaturated chromophoric groups. In the ultra-violet region 2,000 — 4,000A° too, the wave length and the intensity of absorption band are fairly characteristic of the chromophoric group. At present the method is empirical, the absorption is a function of the electron space cloud and is therefore far less characteristic of the skeleton than the IR spectrum. Saturated compounds, as a rule do not absorb at wave length above 2,000 A° Single chromophores such as —C=C—, C=O, S=O, NO_2 absorb in the U V range and the extinction coefficients vary over a very wide range. Structural investigations rely on the fact that rough position and intensity of the absorption bands indicate the main chromophoric groups present ; small shifts in the wave length of absorption and λ max may result from small changes in structure, substitution and conjugation. Thus it is seen that the spectrum of a compound when correlated with data from the literature for known compounds can be a valuable aid in determining the functional groups in a molecule. A tabulation of some of the isolated chromophoric groups is given in the table I.

Table I.

Chromophore	*Exampe*	*λMax*	*Emax*	*Solvent.*
$>C=C<$	Ethylene	171	15,530	Vapour
$-C\equiv C-$	2—Octyne	178	10,000	Heptane
		196	ca, 2100	Heptane
		223	160	Heptane
$>C=O$	Acetaldehyde	160	20,000	Vapour
		180	10,000	Vapour
		290	17	Hexane
$-CO_2H$	Acetic acid	208	32	ETOH
$-NO_2$	Nitromethane	201	5000	MeOH
		274	17	MeOH
$-C\equiv N$	Acetonitrile	167	weak	Vapour

If two or more chromophoric groups are present in a molecule and they are separated by two or more single bonds the effect on the spectrum is usually additive ; there is little electronic interaction between the isolated chromophoric groups. However, if the two chromophoric groups are separated by only one single bond i.e. if we have a conjugated system, a large effect on the spectrum results because the π electron system is spread over at least four atomic centres. When two chromophoric groups are conjugated the high intensity i.e. ($\pi \rightarrow \pi^*$ transitions) band is generally shifted 15-45 mμ to the longer wave length with respect to the unconjugated chromophore. Examples of various conjugated chromophoric groups are given in the table II.

Table II.

Chromophore	*Example*	*λmax*	*Emax*	*Solvent*
$>C=\overset{\mid}{C}-\overset{\mid}{C}=C<$	Butadiene	217	20,900	Hexane
$>C=\overset{\mid}{C}-\overset{\mid}{C}\equiv C-$	Vinylacetylene	219	7600	Hexane
		228	7800	
$>C=\overset{\mid}{C}-\overset{\mid}{C}=O$	Crotonaldehyde	218	18,000	Ethanol
		320	30	
		224	9750	
		314	38	
$-C\equiv C-\overset{\mid}{C}=O$	1 Hexyn-3-one	214	4500	Ethanol
		308	20	
$>C=\overset{\mid}{C}-CO_2H$	cis-crotonic acid	206	13,500	Ethanol
$-C\equiv C-CO_2H$	n-butyl propiolic acid	ca 210	6000	Ethanol
$>\overset{\mid}{C}=C-C\equiv N$	Methacrylonitrile	215	680	Ethanol.

The ultra violet spectra of $\alpha-\beta$ unsaturated ketones, $\alpha-\beta$ unsaturated aldehydes and conjugated dienes lend themselves to an excellent numerical correlation depending on the number of alkyl, alkoxyl or acetoxyl substituent groups attached to the ethylenic $=$ bond. The rules are relatively simple for systems containing the $\alpha-\beta$unsaturated ketonic chromophore, In order to estimate absorption of an $\alpha - \beta$ unsaturated ketone, a base value of 215 m. μ is assumed. For an α substituent 10mμ are added ; for each β substituent 12 mμ are added. For each ring (6 membered or less) to which the C = C double bond is exocyclic 5 mμ are added. If the C = C double bond and the carbonyl group are contained in a 5 membered ring (cyclopentenone, 10 mμ are subtracted from the calculated value ; if the C = C double bond is in a 5 membered ring 5 mμ are added. In addition 35 mμ are added for an enolic α or β hydroxyl group, 15 mμ for an α chloro and 23 mμ for an α bromo group. Table III gives some estimated and experimental values.

Table III.

Compound	λ *Estimated*	λ *Observed.*
Methyl vinyl ketone	215	213, (320)
2 Methyl-1-buten-3-one	225	220
3 Penten-2-one	227	224
Mesityl oxide	239	237, 310
3 methyl-3-penten-2-one	237	236
2 Cyclopentenone	217	218, (311)
2 Cyclohexenone	227	225
1 Acetyl cyclopentene	242	239
1 Acetyl Cyclohexene	237	233, (308)
2 Cyclohexylidene cyclohexenone	259	256
2-3 dimethyl-2-penten-4 one	249	246

In contrast to the relatively few absorption peaks observed in the Ultraviolet region for most organic compounds, the Infrared spectrum provides a rich array of absorption bands. Most of the absorption bands cannot be assigned accurately; those that can, however, provide a wealth of structural information about a molecule.

The chemist will usually know what absorption position to expect from a functional group in a given environment. In the absence of steric and electrical effects that would effect the vibrational frequency of a given group, that group would absorb Infrared energy of very nearly the same wave-length in all molecules. For example, absorption owing to the carbonyl stretching vibration of acetone is at the same place as that of di-n-hexyl ketone. On the other hand, it is different from acetic acid (electrical effects) and cyclobutanone (a steric - effect). The most powerful function of infra-red spectroscopy is establishing conclusively the identity of two samples that have identical spectra when determined in the same medium. The region 910 to 1430 cm^{-1} is particularly rich in absorption bands and shoulders and for this it is called the **finger print** region. Although simlar molecules may show similar spectra in the region 4,000 1.430 cm^{-1} there will always be discernible differences in the finger print region. Today to prove the identity of two organic compounds it is not sufficient to state that they have identical mps and mixed mps; the identity of IR spectra is a must.

Table IV.

INFRARED GROUP FREQUENCIES

Group	*Frequencies.Cm*$^{-1}$
O—H (non H bonded)	3,500-3,700
N—N (non H bonded)	3,300-3,500
CH (stretching)	2,700-3,100
—C = C—	2,200-2,260
—C = N—	2,250
C = O	1,660-1,870
C = C	1,600-1,680
NO_2	1,500-1,600
CH (bending)	1,350-1,450
C—F	1,000-1,400
C—Cl	600-800
C—Br	500-600
Anhydride	1,800-1,850, 1,740-1790
Acid Chloride	1,770-1,815
Ester	
Aliphatic, saturated	1,739-1750
Aliphatic, (α-β) unsat.	1,717-1,730
Carboxylic acid	
Aliphatic, saturated	1,705-1,725
Aliphatic, (α-β) unsat.	1,700-1,710
Aromatic	1,680-1,700
Amide	1,630-1,700
Aldehyde	1,695-1,740
Ketone	
Aliphatic, saturated	1,706-1,725
Aliphatic, α-β unsat.	1,665-1,685
Aliphatic, (α-β, α′-β′), diunsat.	1,660-1,670
Aryl. alkyl	1,680-1,700
Diaryl	1,660-1,670
Cyclopentanone	1,745-1,749
Cyclohexanone	1,706-1,720

The introduction of IR spectroscopy has lightened the burden of the organic chemists. In contrast to the hit and miss methods of the classical organic chemists, the IR spectrum reveals at a glance a wealth of information. For example if the spectrum reveals a strong band at ca. 1718 cm^{-1} the compound must always contain a $C=O$ group. But the spectrum by itself does not provide further information as to the nature of the group : the compound could be an aldehyde, a ketone, an acid an ester or amide. Thus in order to define a functional group the spectrum must be examined in detail for other diagnostic absorption bands and used in conjunction with chemical reactions and solubility determinations. How ever, if the spectrum does not contain an absorption band at 1850-1587 cm^{-1} then we could safely assume that the sample does not contain a carbonyl group. Similarly the lack of a strong absorption band in the region 3570cm^{-1} indicated the absence of an OH group ; and it is no longer necessary to waste precious material by attempting to acetylate or benzoylate or determine the percentage of active hydrogen.

In structural studies of natural products the groups most commonly sort are OH, NH, CH_3,$C=O$ and $C=C$ present in saturated and unsaturated systems in open conjugated chains or in rings of various size or type. Table IV gives IR frequencies of the more common functional groups.

NUCLEAR MAGNETIC RESONANCE

No spectroscopic technique including IR spectroscopy is as informative or is more widely used by the organic chemists handling structural problems as the nuclear magnetic resonance (NMR) spectroscopy. After its discovery in 1946 and its application in structural problems in 1953, the tremendous potentiality of the method has been accepted. It does not displace UV or IR but is complementary to them ; however, it gives a straight answer to a specific problem more readily. The organic chemist normally deals with the proton magnetic resonance and uses the term NMR to signify PMR.

NMR spectra are commonly used for integrating the total number of protons in a molecule ; for characterizing the types of protons (as in a methyl, methoxyl, methylene or hydroxyl group) in terms of what is known as the chemical shift from the signal of a standard substance, tetramethyl silane (TMS) and for locating a proton or a group of protons in the neighbourhood in terms of spin coupling. NMR spectroscopy provides a method of confirming the molecular formula based on the proton count ; it gives detailed information on the different kinds of hydrogen atoms in the molecule even when the molecule may have up to 40 hydrogen atoms. For estimating such groups as methoxy and C-methyl it is often simpler and much more dependable than the classical organic methods. The spin coupling patterns (the multiplicity and the coupling constant J) reveal the number and the nature of the bonds separating one proton from another as well as their spacial relationship.

For NMR spectroscopy, unlike IR and mass spectrometry we need quantities of the order of 25-40 mg ; however, special techniques are available for handling quantities as small as 1 mg. Of course the whole of the precious material is recovered by evaporating the solvent. Further the compound has always to be in solution in solvents like CCl_4 deuterated chloroform or deuterium oxide D_2O. A greater flexibility in solvents can be achieved by using deuteropyridine, deuteroacetone, DMSO.

MASS SPECTROMETRY

In the mass spectrometer the molecules of a compound in the gaseous phase are bombarded with low energy electrons (70 eV). An electron is thus ejected from the molecule which then breaks up into a series of fragments consisting of positively and negatively charged ions, radicals and neutral molecules. In the spectrometers the positively charged ions are separated according to the mass to charge ratio (m/e) by a magnetic analyser (single focussing) or a combination of electrostatic and magnetic fields (double focussing) and the mass spectrum is recorded photographically. The intense peak of the highest mass number normally repressents M^+, the ion formed by the removal of one electron from the molecule and therefore the molecular weight. Anomalous molecular weights are obtained if M^+ has broken up before reaching the collector or if two fragments undergo re-combination to form an ion of higher mass than M^+. From the cracking pattern useful information regarding the structure of the molecule emerges ; but caution has to be exercised in their interpretation. It is only when a series of model compounds have been studied that the fragmentation patterns can be applied to the determination of the stucture of a natural product.

One great disadvantage in the mass spectrometer is the exceptionally high cost; a good high resolution mass spectrometer may cost anything up to $ 100,000. Another disadvantage is that mass spectra can only be obtained when the compound is present as a gas, but the minimum vapour pressure required is so small (about 10^{-5} mm of Hg) that most organic compounds can be submitted to mass spectroscopy.

X' RAY ANALYSIS

The X' ray diffraction method has the tremendous advantage of directly yielding the three-dimensional structure of a molecule in a crystal ; yet it is time-consuming that it is not a method of choice unless of course the compound is intractable by chemical methods (such as some stereochemical problems) or the compound has unusual complexity or interesting biological properties (e.g. Vitamin B_{12}). This indeed is fortunate for the organic chemist, otherwise he would be out of business and would be merely supplying suitable crystals to the crystallographer.

Briefly the crystallographer measured the dimensions of the unit cell of the crystal and determined the number of molecules within the unit cell ; a molecular structure fitting these requirements was then favoured. X'ray analysis has given conclusive evidence for the steroids, alkaloids such as strychnine, colchine, calycanthine, penicillin and vitamin B_{12}.

OPTICAL ROTATORY DISPERSION

Although optical rotatory dispersion or the variation of optical rotation with wave-length had been known for a long time to the theoretical and physical chemists, its impact on structural studies in natural products was felt only after the pioneering work of Djerassi at Stanford University. One limitation, no doubt, is that the substrate has to be optically active, but the limitation is negligible in the natural products field as the vast majority of natural products are optically active. Most of the work on optical rotatory dispersion studies has been on carbonyl containing compounds since these absorb in the region of the spectrum 280 — 330 mμ which is accessible to the commercial spectropolarimeters and possess sufficiently low extinction coefficients for rotational measurements to be conducted through the UV absorption maximum. The most important applications of ORD lie in assignment of relative and absolute configurations and for the solution of conformational problems, when other physical measurements have failed. In addition ORD can be employed for structural purposes such as the location of a carbonyl chromophore in polycyclic systems. This has found wide application in steroids, tetracyclic and pentacyclic triterpenes.

It is difficult for chemists trained after the world war II to imagine how the structures of complex molecules could be solved exclusively by chemical methods. Yet these problems were solved in that way, if one is willing to overlook absolute configurations. It took years of painstaking research by a large group of chemists on a single natural product.

An investigation was always started by the detection of the functional groups present, and the preparation of derivatives. The complex molecule was then degraded and the fractions separated. Each fraction was then studied chemically until it was identified or degraded further into known products. With this information, it was possible to reconstruct the original molecule with some degree of accuracy provided that no rearrangements took place during the degradative steps. One of the drawbacks was that relatively large amounts of material were required for the numerous degradations and reactions. In this respect, one could understand why the earlier investigators chose alkaloids like quinine, morphine strychine ; yet without the advantages of today the achievements of earlier chemists are noteworthy.

Molecules which contained many different types of rings presented much more difficulty to the investigator who had to rely only on the chemical methods. Satisfactory degradative reactions were difficult to come by for frequently they involved rearrangements or often complete destruction., this was particularly so with heterocyclic compounds. The chemistry of strychine and brucine provides us with classical examples of the pitfalls, degradative work on heterocyclics could lead us to.

Today we have reached the stage when the elucidation of structure is initiated by purely physical methods and then supplemented by chemical evidence. Indeed when small quantities of material are available, sometimes the confirmation of structure established by physical methods is often attempted by direct synthesis. In the earlier days the isolation of a natural product was only the beginning of a far more difficult and painstaking job to elucidate the structure, and this was often spread over a decade or two at best. On the other hand structural studies with the help of the new physical methods take a fraction of the time one would have expected. For instance the elucidation of the structure of quinine took about twenty five years and the synthesis was spread over a period of about fifty years. In contrast reserpine, an alkaliod of comparable complexity, was first isolated in 1952. Its structure as determined and the compound was synthesized by **R.B.** Woodward within a span of five years.

One should bear in mind that the earlier efforts were confined to the major constituents present in plant and animal products, the minor constituents were invariably missed. On the other hand, with the refinements of experimental techniques available today, the minor constituents are always tracked down. Studies in Rawvolfia serpentina and Lochnera rosea are examples where the minor but yet the therapeutically active constituents have been carefully separated and then isolated from a host of other alkaloids devoid of such activity. The complex alkaloid mixture from Lochnera rosea has been separated into 63 different alkaloids, a phenomenal feat which could possibly have not been effected without the modern experimental techniques. Incidentally one of the alkaloids, namely vinblastine, has been found to be active against experimental leukemia in mice.

SECTION F—SOCIAL SCIENCES

Presidential Address

THE DEMOGRAPHIC REVOLUTION IN CEYLON

by

S. SELVARATNAM

This is the second time in three years I have been afforded the privilege of delivering the Presidential Address from the Social Sciences Section. Mr. Carl Jeyarajah, who was elected President of this Section for 1970, left the Island to accept an assignment in Bangkok with the Economic Commission for Asia and the Far East. It was towards the end of September this year that the Council of our Association elected me to fill the resulting vacancy. My address to you this morning had, therefore, to be prepared at very short notice and this explains partly the decision to choose a topic from the narrow field of my specialisation.

There is also another reason, perhaps a more important one, why I selected "The Demographic Revolution in Ceylon" as the subject for my Presidential Address. In Ceylon, during the past two decades, no socio-economic problem has been more important than that of population growth. Even to-day the high rate of population increase towers high over all the social and economic problems. It heads the parade of factors that cast long shadows on the development scene and continues to pose a real challenge to the economic progress of the country. But the most disturbing feature of the population predicament in Ceylon is that inspite of its seriousness, the problem does not seem to have been given the recognition that it deserves. Though a lot has been said and written on the subject in the recent past, it is disheartening to note that to-day not many are inclined to consider the population question, let alone support the view that in developing countries like Ceylon, rapid population growth is the greatest single obstacle to economic development, social progress and improvement in the standards of living of the people. This neglect of and apathy towards the population problem may partly be due to a deference to national, political or religious prejudices ; but it has largely to be attributed to a lack of appreciation of the impact of a high rate of population growth on the development efforts of the country. There is thus a clear need to re-state the problem and its implications, particularly in the light of recent trends, with a view to providing a basis for the formulation and execution of suitable population policies and programmes. I do hope, Mr. President, that this address will help to achieve that objective.

A rapid increase in population has been the chief demographic feature in Ceylon since the Second World War. Estimates based on census data show that, whereas between 1871 and 1946 Ceylon's population grew at an average annual rate of about 1.4 percent, between 1946 and 1963, the rate of growth averaged about 2.8 per cent per annum. The significance of these rates will be readily appreciated when one realises the fact that it took 75 years for our population to increase by about 4 million between 1871 and 1946, but it took only 17 years for the population to increase by another about 4 millions between 1946 and 1963. What are the factors that were responsible for this phenomenal speed-up in population growth during the post-war period ?

The growth of the Ceylonese population between 1871 and 1946 has been due to two factors-natural increase (excess of births over deaths) and migration increase (excess of immigrants over emigrants) During this period migration played a very important part, contributing to as much as 58 percent of the increase in population between 1871 and 1901 and about 16 percent between 1901 and 1946. On the average, during the entire period from 1871 to 1946 migration contributed to about 27 percent of the increase in population. But the picture after 1946 is very different. As a result of several restrictive measures adopted in and after 1948, migration ceased to make any significant contribution to population growth between 1946 and 1963. In fact, it is estimated that only 2 percent of the increase in the population during this period has been due to migration. Yet, the average annual growth rate of our population between 1946 and 1963 was almost double the rate recorded for the period 1871 to 1946. The acceleration in the rate of growth of the population since 1946 has therefore been due to an increase in the rate of natural increase caused by the widening disparity between the birth rates and death rates of the country.

At the begining of this century, Ceylon had a crude death rate of about 30 per thousand of the population and this was one of the highest death rates in the world. The death rate had fluctuated violently around this level between 1900 and 1920. However, since 1923 this rate showed a definite tendency to decline. By 1932 the death rate had come down to about 21 per thousand of the population and remained more or less at this level until 1946 except in 1935, when as a result of the severe malaria epidemic, the death rate moved up to about 37 per thousand of the population. But between 1946 and 1947, there was a sharp and dramatic decline in mortality, the death rate suddenly dropping from 20.3 in 1946 to 14.3 in 1947. This revolutionary decline in mortality by about 30 percent in one year is an event unparalleled in the annals of world demography. Since 1947, the death rate of the country continued to decline slowly but steadily and by 1963 stood at 8.5 per thousand of the population. The 1963 rate easily placed Ceylon among the countries of the world with the lowest mortality rate.

The spectacular decline in the death rate during the early post-war years was chiefly the result of the island-wide D.D.T. campaign started in 1945 against malaria, a disease which until 1946 was the chief cause of morbidity and mortality in the country. The campaign was vigorously and intensively continued upto 1949 and it is believed that malarial mosquitoes were almost completely eradicated from the island during the period of the campaign. Once malaria was eradicated, the death rate, which stood high mostly on account of this disease, suddenly started to come down. The use of D.D.T. also brought about a considerable decline in mortality from other infectious diseases which are spread by insects. In addition to the anti-malaria campaign, the widespread use of drugs and antibiotics to control endemic diseases also contributed to the precipitate decline in mortality during the post-war years.

The remarkable reduction in mortality that was achieved after 1946 was not accompanied, or even followed, by a comparative or significant reduction in fertility which for long continued to remain almost unchanged at traditionally high levels. For five decades from 1900 to 1950, the crude birth rate of Ceylon had remained fairly steady around 38 per thousand of the population, although the rate was subject to some fluctuations. The sharp decline in morbidity and mortality since 1946 helped to increase the fertility somewhat in the late 1940*s*. The birth rate which was 37.4 in 1946 increased to 39.7 in 1948 and remained at that level until 1951. During the 1950*s*, the birth rate showed signs of decline interrupted in 1955 and again in 1959. The crude birth rate in 1963, however, was 34.4, and this was, in comparision to a large number of countries, a very high birth rate. It will therefore be seen that while the death rate dropped from 20.3 in 1946 to 8.5 in 1963, the birth rate declined from 37.4 to only 34.4 during the same period. Rapidly falling death rates and almost static birth rates resulted in very high rates of population growth since 1946.

Thus, in Ceylon, the period immediately following the second world war witnessed a demographic revolution, the pace of which is without parallel anywhere in the world. Unlike other types of revolution, which have been preceded by long periods of preparation, the demographic revolution descended upon us very suddenly. It was also a peculiar revolution in the sense that the whole process was accomplished without any major changes in existing structures and institutions and without any sacrifices or loss of lives. Indeed it was a revolution that saved many lives and helped to produce still more lives. This was the significant contribution of the revolution and this was also its painful aspect. The sharp decline in mortality combined with constant and high fertility had the immediate effect of boosting the rate of population growth to un-precedented levels causing what is very often termed the " population explosion ". The rapid and accelerating population increase constitutes the most dangerous barrier that faces us in our drive towards raising the level of productivity in an effective and efficient manner. The runaway multiplication of people is already retarding our economic advance and holds the threat of economic stagnation and deterioration. I shall deal with this aspect in greater detail later.

I should now like to refer to the tendency among many to compare the post-war demographic development in Ceylon with what happened in Europe during its post-modernisation period. Immediately after the Industrial Revolution, countries in Western Europe experienced an upsurge in population growth as a result of improvements in the standards of living of the people and the advances made in medical knowledge and public health measures. There is, however, an essential difference between the demographic experience of the West during the 19th century and that of Ceylon during the 20th century. In the West, the whole process of declining mortality was extended over a period of 50 to 100 years and was dependent in the early stages on the more or less direct effects of economic development. By contrast, in Ceylon, the dramatic decline in the death rate was accomplished within two to three years and was the result of increasingly effective public health measures and improved medical knowledge. In fact, the sharp fall in mortality rates in Ceylon took place during the very early stage of the country's economic development and long before planning for such development was introduced in the country. It is thus clear, that what countries of Western Europe went through in the 19th century was only a demographic transition ; what Ceylon experienced after the second world war was a demographic revolution.

Further, in the industrialised countries of the West, the rate of population growth came to be checked essentially by a fall in the birth rates which followed improvements in the living standards of the people. It is to this factor and not to anything else that countries in Europe and America owe their present rather manageable rates of population growth. In other words, while in the West, the very factors that were responsible for the decline in the death rates also brought about a decline in birth rates, in Ceylon, not only has the decline in death rates been faster, but this decline has not been followed by a comparative decline in the birth rate. The historical fact is that during the 100 years of demographic transition in Europe as birth-rates followed death rates downward, the population growth rates never exceeded 1.5 percent, and in most countries, most of the time, did not exceed 1 percent. Also conditions prevailing in countries of Western Europe during the early stages of their development were far more favourable to lower rates of population growth. The birth rates in those countries at that time were much lower than that of Ceylon during the post-1946 period, the death rates remained at fairly high levels and by the time the expanded public health programmes brought about drastic reduction in the death rates, the infra-structure of industrialisation was already in place. Since the demographic revolution in Ceylon has taken place in a matter of few years, we are to-day experiencing a rate of population growth which is significantly more rapid than what the West experienced in the 19th century.

It is, however, very heartening to note that the rate of growth of our population has decreased from 2.8 in 1960 to about 2.2 in 1969. The fall in the growth rate during these years has been largely due to a gradual decline in the birth rate from 36.6 in 1960 to 30.4 in 1969. This decline in the birth rate is only a continuation of the trend observed in the 1950s. On the other hand the death rate did not register any remarkable reductions. The death rate dropped from 8.6 in 1960 to 8.0 in 1961 ; then rose to 8.8 in 1964 and fell to 7.5 in 1967 and then rose to 8.3 in 1969. Nevertheless, the 1969 growth rate is well above western levels, and, if continued, will lead to a doubling of the population in 30 years.

In Ceylon, since the death rates have reached a fairly low level and have remained more or less stabilized at that level over a long period, the future rates of population growth will be determined to a large extent by the level of the birth rates. It is therefore important to analyse the fertility decline of the 1950s and the 1960s with a view to evaluating the prospects for a further decline in the future. " Several reasons have been advanced by various persons to explain the recent decline in the birth rate, mostly based on the data published by the Registrar-General. Jayawardena and Selvaratnam have argued that the increase in the mean age at marriage of women has largely been responsibile for the decline in the birth rate observed in recent years. The most detailed analysis of recent trends in fertility has been undertaken by Wright. He has shown that the decline in the birth rate between 1953 and 1963 was due primarily to changes in the age structure and to the rising age at marriage. Marital fertility changed very little. The continuing decline between 1963 and 1968 occurred in spite of, rather than because of, changes in the age structure and was caused by continuing postponement of marriage and decline in marital fertility among women over 25 (and possibly among women over 20).

" Chandrasekaran has observed that the declining birth rate in recent years might well be but a temporary phase and that the births saved in the past few years by delay in age at marriage might be made up during the course of the remaining reproductive years of these married women. This appears unlikely, since the declining marital fertility rates at the older ages in recent years are occurring in cohorts that were marrying later than their predecessors, and there is no reason to expect a reversal of this trend. Nevertheless the future course of fertility is indeed difficult to predict, not the less so because the age at marriage is unlikely to rise much above its present levels, and future decline in fertility will therefore be almost wholly dependent on a further decline in marital fertility. That fertility will level off at its current rates remains more than just a theoretical possibility. " (Selvaratnam, Wright and Jones, 1970).

So far we have seen the manner in, and the rates at which our population has been growing over the past nearly 100 years. What about the future ? How fast and how large will our population grow ? Three sets of population projections—high, medium and low—based on three alternative assumptions regarding the future course of fertility and one assumption about future mortality were recently prepared by Selvaratnam, Wright and Jones at the Ministry of Planning and Employment. (Selvaratnam, Wright and Jones, 1970). These projections cover a thirty-year period, 1968 to 1998, and give an indication of the possible maximum and minimum level that our population will attain during this period. According to the high projection which assumes that the base year age-specific fertility rates will remain constant over the 30 years, the estimated population of about 12 million in 1968 will increase to 26.2 million in 1998. The medium projection based on the assumption of a slow decline in fertility will result in a total population of 22.7 million, while the low projections which correspond to the assumption of a rapid fertility decline will give a population of 19.7 million in 1998. In other words, if there were to be a slow decline in the fertility rates, our population in 1998 will be 3.5 million less, and if fertility declines rapidly it will be 6.5 million less than if the fertility rates were to remain unchanged at the 1968 levels. I also wish to emphasise that since the present age-structure of the population has high built-in potential for rapid population growth, a 50 percent increase in population during the next 23 years will take place even if fertility declines rapidly.

Let us now examine briefly the average annual rates of growth implied by these projections. Since mortality is assumed to decline further in all three projections, the average 30-year rate of population growth under assumptions of constant fertility will be 2.6 percent, which is slightly higher than the rate of natural increase of 2.4 percent observed in 1969. The medium projections start with an average growth rate of 2.5 percent during the first five years gradually decreasing to 1.8 percent during the last five years of the projection period, giving an average annual growth in the population of 2.2 percent during the 30-year period. The average annual rate of growth implied by rapidly declining fertility, i.e. the low projections, would be 1.7 percent during the 30 year period but as low as 1.4 percent by the final decade, a rate that would nevertheless still exceed current rates of increase in Europe and North America. These average growth rates also mean that according to the high projection, the 1968 population will double in about 26 years, while the doubling will take about 33 years in the medium projection and 45 years in the low projection. To put it in another form, if our present high fertility rates continue without any change into the future, the year 1994 when we will probably number some 24 million is only as far in the future as the year 1946 is in the past.

The rapid increase in our numbers is not just a future danger ; it is at present a major cause of a series of social and economic problems in the country. Firstly, compared to most of the countries in the region, Ceylon is already densely populated with about 500 persons per square mile. The pressure of population particularly on the cultivated land is very heavy. According to a recent study by Jones and Selvaratnam, while the area cultivated has increased by about 0.7 percent per annum between 1946 and 1969, the rural population has increased by about 2.5 percent per annum during the same period. Consequently, the density of rural population per cultivated acre has increased steadily from 1.34 in 1946 to 2.02 in 1969. (Jones and Selvaratnam, September 1970) Since the amount of land available for new cultivation is very limited, and since the rate of expansion of cultivable land is also very slow, a rapidly increasing population will only further aggravate the problem of fragmentation and uneconomic size of land holdings.

Secondly, the rapidly growing population will have a very serious effect on our food situation. During the past twenty years or more, we have made very considerable progress in the matter of increasing the production of food by expanding the area under cultivation as well as by increasing the yield per acre. The total production of paddy, for instance, registered an increase from 14.5 million bushels in 1950 to 65.9 million bushels in 1969. Yet to-day we are a fooddeficit nation importing annually about Rs. 970 million worth of rice and other essential food items from other countries. It would thus appear that increased production has been largely used for feeding the increasing population and has not been sufficient to narrow the gap between domestic requirements and domestic production to an appreciable extent. A developing country like Ceylon which has to make huge purchases of rice and other foods from abroad in order to meet the needs of her people inevitably weakens her foreign exchange position, thereby putting a brake on her own industrial and agricultural development, and postpones the day when she will be independent of foreign economic aid. For a long time we have also been experiencing a deficiency in regard to the nutritional quality of our food since commodities like milk, meat, fish, eggs, fruits and vegetables are not sufficient for our requirements and do not form an adequate portion of the average diet. In the context of a rapidly increasing population, we must greatly increase both the output and the nutritional value of food. We must produce more both to feed more people and to feed people more.

Thirdly, the high rate of population increase will adversely affect the employment situation in the country. Already, the problem of unemployment has assumed very serious proportions with about 500,000 persons or 12 percent of the workforce remaining unemployed. The level of unemployment in Ceylon is very high and has been the result partly of the high rate of population increase. The population explosion of the late 1940s resulted in an explosion of the workforce in the 1960s. This rapid and sudden increase in the number seeking employment was not matched by an equal increase in the rate of employment creation. In addition to the existing backlog of unemployed, one has also to take into account the future additions to the labour force. According to the labour force projections recently prepared by Srivastava, Jones and Selvaratnam at the Ministry of Planning and Employment (Srivastava, Jones and Selvaratnam, June 1970), the labour force is expected to increase by more than 50 percent during the 15 years following 1968. It will more than double in the 30-year period 1968 to 1998, even if fertility declines rapidly, but it will double in only 25 years if fertility does not decline at all. During the decade 1968-78, the labour force will increase by 3.0 percent per annum, more than double the rate at which employment increased in the post-war period upto 1968. In any event, the net addition to the labour force will be over 100,000 per annum " Unless action is taken to provide sufficient avenues of employment, the problem of unemployment is likely to get progressively worse every year, since high rates of population growth continue to add new entrants to the labour force in an already serious employment situation ". (Selvaratnam S. 1969).

Fourthly, at a time when we are striving to accelerate the process of economic development, a high rate of population growth would exert an excessive pressure on our limited resources by diverting an inordinately high proportion of these resources away from productive investment purely to maintain low levels of existence and thus restricts the expansion of the economy. The purpose of economic development is to improve the levels of per capita income by raising total production, and this means increasing production at a rate faster than the rate of population growth. Any population growth requires some investment of available capital just to maintain the same level of per capita Gross National Product. The higher the rate of population growth, the greater the proportion of the available capital that must be used for investment simply to maintain constant per capita GNP and the less there is available to increase per capita GNP. The main source of capital formation is domestic savings effected through refraining from consuming some part of the current gross national product and setting aside that part for the purpose of future production or for the rendering of future useful services. Though imported capital also contributes to capital formation in a large number of developing countries, by and large, the capital required for the development of a country must be generated by the people through savings and the useful employment of these savings. To-day our country adds over 300,000 to its population every year and has to use up a large part of the increase in the national income to feed additional mouths with very little left to improve present living standards. From the demographic point of view, the saving potential depends, other things being equal, on the rate of increase of population and also on the ratio of employed persons to total population.

The sharp and sudden decline in the death rates during the post-war period without any significant fall in the birth rates has had far-reaching effects on the age-structure of our population. At present, our age-sex-pyramid is much broader at the base with the number of children in the age-group 0-14 years forming about 40 percent of the total population. The corresponding proportion in the developed countries is very low ranging from 22 to 30 percent. Persons in the working age, 15 to 64 years, constitute only 56 percent of the total population in Ceylon while in advanced countries they account for 65 percent or more of the total population. Thus in Ceylon, high fertility combined with declining mortality has resulted in a population with a high proportion of children in the non-productive ages and a relatively smaller proportion of those in the working ages. The bottom-heavy age-structure simply means that the childhood dependency in our country is very heavy with about 72 child dependents per 100 persons in the working age while in England and other developed countries there are only about 35 children per 100 workers.

From the point of view of the development of the country, there are two distinct disadvantages to an age structure of the type found in Ceylon. In the first place, the broad base to our age-sex-pyramid illustrates the fact that each year the cohort of young men and women entering the years of fertility is significantly larger than the number of older people growing out of the age of fertility during that year. As pointed out earlier, the present age structure of our population has very high built-in potential for further rapid increase in the future. Secondly, the large number of dependent children relative to the number in the labour force increases the burden of dependency, tends to promote spending for immediate consumption, to restrict both private and public savings and hence to inhibit productive investment. Children below 15 years are economically dependent : they have to be fed, clothed and educated ; and this increased burden on the economically active sector of the population means that resources available for economic development have to be directed to provide various facilities for them. In other words, the present age-structure of Ceylon's population tends to divert whatever savings have been accumulated each year into social overhead expenditure, which have only remote, if not little, effects on economic growth instead of being converted into capital which contributes directly to the development of the economy. Hans Singer aptly describes the problem when he says that " one of the troubles of under-developed countries is not so much that there is not enough investment but rather that there is too much of unproductive investment. Practically all investments which occur in under-developed countries is investment in the feeding and bringing up of a new generation for productive work instead of investment in economic development". (Singer 1955) The higher the rate of population increase, the greater the required amount of unproductive investment of this kind.

During the period following the Second World War, we in Ceylon witnessed not only an upsurge in population growth but also a proliferation of a wide range of social services and transfer payments. The Government was subject to strong political pressures to provide for the people an expanded programme of education. health, housing and other social welfare activities on a per capita basis. The progress made particularly in the field of education and health has been very significant. Beginning from October 1945, all education in the Island from kindergarten to the University was declared free and under this free education scheme no tuition fees are charged in government schools, the Universities and the Technical Colleges. For a long time the Government assumed the major responsibility for the medical care of the people and towards this end established hospitals and dispensaries throughout the country. To-day, ordinary out-door treatment is free at out-patients departments of all Government hospitals and dispensaries and in-door treatment in non-paying wards is provided free to all patients. A separate Department of Housing was set up in 1953 to assist private individuals to construct dwelling houses by granting loans for the purpose, as well as to construct housing units particularly in the urban areas. Starting in the early 1950s, the Government has been issuing to all persons aged 1 year and over two measures of rice at subsidised prices. This scheme has subsquently been modified and at present each person is given one measure of rice per week free of charge while a second measure is sold at subsidised prices. The Department of Social Services administers a variety of assistance and relief programmes to help the poor and needy.

These and other population-linked expenditures occupy a very important place in the Government budget to-day. While in 1947/48, the expenditure on social service programmes formed about 25 percent of total Government expenditure, in 1968—69 this proportion was as high as 39 percent. A rapidly increasing population together with rising unit costs of providing most of these services pushed up rapidly the total outlay on these services. According to a World Bank Study of government expenditure patterns in 46 developing countries, Ceylon had the highest level of expenditure on social services (16% of G.D.P.) among those countries. Within its 18-country group with per capita incomes between U.S.$ 125 and $249, Ceylon occupied fourth place in the share of G.D.P. devoted to education, second place in health and first place in housing and general welfare services. These social welfare type expenditures have been part of the implementation of government policy to achieve greater equality in the distribution of income. They have not been without their opportunity costs. Although they have, by no means, been irrelevant to the economic growth process, since they have contributed to raising the quality of the labour force and perhaps also to the maintenance of political stability in the country, they have been at the expense of higher levels of expenditure on more directly productive investment.

In Ceylon, the present level of expenditure on social services is very high for a developing country. In the context of a rapidly increasing population and limited capital resources, we cannot hope to achieve rapid expansion in our agricultural and industrial production concurrently with a rising expenditure on social services for the people. Nevertheless, for the future, the main point to be stressed is that the aim of at least maintaining the present per capita standards of a variety of social services is more or less immutable. Therefore, the increase in expenditures on these services will be linked directly with the increase in population. It thus becomes important to determine the effect of a slower rate of population growth on government expenditures for education, health, the food subsidy etc. because whatever is saved in reaching the goals for these services could be used either to reach higher goals in terms of the quality of these services or invest in other directly productive activities.

Separate studies have been undertaken recently to measure the impact of varying rates of population growth on the costs of providing education, health, transport, food subsidies etc. These studies were based on the three alternative population projections of Selvaratnam, Wright and Jones except the education study which used a different set of population projections prepared by Lesthaeghe and Chi at the Brown University, U.S.A. The Lesthaeghe-Chi projections, however, incorporated alternative fertility trends that are roughly comparable for most of the projection period to those used in Selvaratnam-Wright-Jones projections. The results of these studies are indeed very interesting.

The Jones-Selvaratnam study on the effect of alternative rates of population growth on the cost of providing public health care takes into account the fact that the rate of use of the Government health services is greater at the time of birth and infancy than at any other stage of the life cycle except old age. According to this study (Jones and Selvaratnam 1970) the population dependent on public health care in Ceylon which was estimated to be about 10.1 million in 1968 will increase to 21.8 million in 1998 if population trends were to follow the high projections, and to only 15.8 million or 5.3 million less if the rates of population growth were to coincide with the assumptions of the low projections. Similarly, if availability of health services per head is to be expanded by two thirds during the 30 year period, the number of doctors required will increase by 233 percent according to the high projections and only 146 percent according to the low projections. Roughly the same figures apply to requirements for hospital beds. Health costs would rise much less rapidly and the savings over the 30 year projection period would be roughly Rs. 3,356 million or 17 times the entire sum spent by the government on health services in 1968. It is true that most of the savings come towards the end of the period but during the first twenty years Rs. 1,198 million or six times the 1968 expenditure will be saved while during the first 10 years the amount saved will be Rs. 228 million or more than the entire 1968 expenditure.

In the case of education, savings take a little longer to build up because of the delay before the decline in fertility affects the number of school entrants. But subsequently the benefits of a decline in fertility build up rapidly. The results of the Jones-Kayani study indicate that by 1988, primary school enrolments would have to be 70 percent higher if fertility stays constant than if it falls rapidly ;

total costs of primary and secondary education would be approximately 50 percent higher. Over the 30 year period from 1968 to 1998, the educational status quo can be maintained at a saving of Rs. 5,882 million if fertility falls rapidly or 15 times the entire expenditure on education in 1969. During the first 10 years savings would approximately equal the total 1968 expenditure. (Jones and Kayani, June 1971).

The effect of varying rates of population growth on the costs of public transport in Ceylon has been the subject of a recent study by Jones and Selvaratnam. (Jones and Selvaratnam, October 1970) This study shows that the size of the annual deficits would increase very rapidly such that by 1978 receipts cover only between 76 and 80 percent of the costs and by 1988 only between 61 and 64 percent of costs. However, trends in population growth do not make a great deal of difference to the gap between costs and revenues, particularly during the first ten years. Since trends after that period are so uncertain, and since a fare increase will almost certainly have to be introduced by that time, it would be unwise to make very much out of the difference between the high and low projections after 1978.

The Selvaratnam-Jones study on the impact of alternative population growth rates on the food subsidy programme shows that the cost of the food subsidy would increase much more rapidly if fertility remains constant at the 1968 level. The total savings resulting from a decline in fertility would amount to some Rs. 2,700 million or slightly more than the savings resulting in the health field if the health status quo is maintained.

The general message of these studies is very clear but disturbing. If the current high rates of population growth were to continue, we will be compelled to spend an ever-growing larger share of our potential income just to maintain the existing levels of social services, and there will be hardly any resources available for our programme of economic development which is pointedly begging more serious attention. The rapid expansion in population which we are likely to experience in the future will not only tend to reduce the flow of investment funds ; it will also mean that the capital available for investment in industry and agriculture will have to be spread thinly over the labour force. In other words, each pair of working hands will be backed only by a few rupees of capital, with the result that productivity will suffer and living standards will go down instead of going up. There will also be an increase in our demand for aid and trade concessions. More aid will perhaps be needed just to maintain the present slow rate of development. Thus, the future prospects of our population appear ominous, foreshadowing economic deterioration or collapse.

I do not, however, want to sound a pessimist and an alarmist. I must say there is still hope for our economic salvation, for improving our present low levels of living and for leading our people towards plenty and prosperity. If we can see disturbing facts squarely, if we can identify the problems, if we are willing to take effective measures to overcome them, we can surely prevent the haunting presentiments from becoming realities. The several studies to which I referred to earlier and which have warned us of the dangers of high rates of population growth have also given us hope for optimism. They have shown us a way out of these, difficulties by pinpointing the advantages of a slower rate of population growth. A more slowly growing population would have an important and favourable effect on the age-structure by lowering the proportion of dependent children. With the size of the potential labour force remaining unaffected in the short-run, total output would be at least as high as it would be if there has been no reduction in the rate of growth of the population. But as the given total output would be distributed among a smaller number of persons, income per head will rise relative to what it would be had no decline in growth rate taken place. Because personal incomes would be higher, a higher proportion might to expected to be saved. A slower rate of population growth will enable a larger proportion of the income being released for investment in industrial development and agricultural expansion and thus help to accelerate the pace of economic development.

While emphasising the importance of the population problem it is not my intention to suggest that the comparatively low standards of living of our people has been caused chiefly by population increase and that by merely controlling the growth in numbers, we will be able to achieve a higher living standard. The experience of the West, since the Industrial Revolution, has shown that the economic progress of mankind is dependent, mainly, on improved methods and on an increase in the supply of bigger and better equipment for the people who work on farms and in factories. Perhaps given the improvement in techniques and rapid accumulation of capital, Ceylon may be in a position to support at a higher standard of living, a population much larger than at present. But a more moderate population growth would give us sufficient time and opportunity to develop our economy and maintain the larger numbers at rising levels of living. There is still truth in the old adage that " with every mouth, there is also a pair of hands". But the fact, however, remains that empty hands can achieve very little and that these hands have to be provided with tools and machines if they are to produce the requirements of present day living. The more mouths there are, the less resources there will be available for producing our requirements or providing the instruments and machines. It is essentially because a slower rate of population growth would permit a faster improvement in living conditions, that we in Ceylon should adopt a policy of population control. Such a policy should not be considered a substitute for, but as a supplement to, vigorous efforts towards economic and social development. Therefore the objective of moderating the rate of population growth over a reasonable period must be regarded as an essential element in our strategy for development.

I must, however, mention that in the past the planning authorities have recognised the urgent need to slow down the rate of population growth with a view to assisting the country's development efforts. It was in 1959 that the National Planning Council published a very comprehensive development plan covering the 10-year period, 1959-1968. The implications of the post-war rapid increase in population were not lost on the authors of the plan. Indeed, written as it was at a time when " the demographic obstacle to economic betterment " was typically given rather short shrift by development economists, the strong emphasis given in the plan to population problems is noteworthy and consistent with the economic sophistication and realism that characterised the plan as a whole. The Ten-Year Plan recognised that increasing population density and food problems were not the only economic problems resulting from accelerated rates of population growth. The key problems were rather those stemming from the dynamics of a rapidly growing population, namely, a high proportion of dependants in the total population and its effect in depressing the rate of investment and in slanting the investment mix away from directly productive investments towards meeting the social needs of the rising population. The Plan concluded " It is clear that unless there is some prospect of a slowing down in the rate of population growth and of relative stability in at least the long run, it is difficult to envisage substantial benefits from planning and development " (National Planning Council 1959).

There are only three possible ways in which we can deliberately plan to bring about a reduction in the rate of growth of our population to a level consistent with the requirements of our economy. These are to step up the migration rate, to increase the death rate or to reduce the birth rate. The first choice is wholly inadequate since migration on a scale significant enough to be decisive is not practicable. To-day international migration has virtually been halted because countries concerned with their own future crowding are understandably reluctant to complicate the situation by accepting more than a very limited number of foreigners. The few Ceylonese who succeed in obtaining citizenship of other countries are invariably those who have acquired specialised skills and training and whose services are urgently needed in our own country. The second alternative of attempting to limit population growth through planned increase in mortality must be ruled out on ethical, social and political grounds. Hence the only course appears to be a humane and rational reduction of the birth rate. In the same way that we have reduced the impact of nature's destructive forces through control of diseases etc, we should apply some check upon nature's productive forces.

It is true that during the past few years our birth rates have shown a tendency to decline, but this decline has been very very slow. In fact, as I observed earlier, some scholars have expressed the view that the recent decline in birth rate may only be a temporary phenomenon and that there is a likelihood of this rate returning to its original high levels. Even if the present slow trend were to continue, it will not be sufficient to reduce the rate of growth of the population to the extent desired within a reasonably short period.

What we need is a very drastic reduction in the birth rate comparable to the reduction in the death rate that occurred after 1946. In other words, we should have another demographic revolution—I mean a revolutionary decline in the birth rate.

Is it possible to bring about a substantial reduction in our birth rates within a few years ? In most countries of the world, the decline in fertility has been achieved rather slowly as the social and economic level of the population improved and the population itself was sufficiently motivated to take action to control its fertility. In the Western World, birth rates actually began to decline even before scientific birth control techniques were brought into use. The vast social changes that took place as a result of industrialisation, increase in the standards of living, urbanisation and spread of education were responsible for changing the attitudes of people towards family size. The introduction of " new techniques " only helped to accelerate the pace of fertility decline. Ceylon in its present position cannot afford to wait till economic advancement by itself would accomplish a substantial reduction in the birth rate in any feasible time-frame of the future. The gravity of the problem demands a more direct and conscious approach by the adoption of a comprehensive national family planning programme as an integral part of the development plan.

This does not mean that no attempt has so far been made to preach the gospel and spread the practice of family planning in our country. Pioneer work in this field was started by the Family Planning Association of Ceylon as far back as 1953, and thanks to the efforts of this Association, in Ceylon, family planning is no longer a subject discussed in private and practised by only a few. In 1965, the Government openly stepped in to support the family planning programme and to-day family planning work covering the entire population is a routine activity of the Ministry of Health and is integrated into its maternity and child health programme. Studies carried out in various parts of the country indicate that a majority of the people are now aware of the need for family planning and norm of a small family of 2 or 3 children is finding acceptance everyday. But what has so far been done by way of family planning appears to be insignificant in relation to the magnitude of the problem. The evaluation studies undertaken so far show that during the first four years of launching a modest programme, the performance has lagged behind targets. We have therefore to enlarge the scope of the programme and step up considerably the pace of its implementation if we are to succeed in bringing about a remarkable reduction in the present levels of fertility.

The task before us is a challenging one. It requires the highest priority in official planning and it needs the fullest support of non-governmental and voluntary organisations. Numerous traditional, political and social factors will continue to act as inhibitions and obstacles in the path of progress in family planning. The government alone cannot therefore sustain an effective programme or even formulate a bold policy. Enlightened public opinion in support of official policies is an essential concomitant for success. A special responsibility falls on those who are in a position to influence the thinking of others. The opinion leaders in all walks of life have to understand the gravity of our population problem, actively participate in the programme and exert their influence to generate a mass desire for planned parenthood. Of course, ultimately the success of the programme will depend on the decision of thousands of couples to limit their family size. The family planning programme should therefore become a people's programme.

In conclusion, I wish to say that the total expenditure on family planning in Ceylon at the moment including foreign contribution is only Rs. 4.5 million a year and the local contribution constitutes only 0.1 percent of the Government budget. Recently Jones and Selvaratnam have estimated that the cost of a substantially expanded family planning programme would amount to approximately Rs. 506 million over the 30 year period 1968 to 1998. This cost will be less than one percent of the Ceylon's government current account budget for social services. The Jones-Selvaratnam study has clearly shown that a family planning programme substantially more expensive would be justified in terms of the savings that would result in expenditures on education, health and food subsidies. " These savings, of course, do not exhaust the range economic benefits of such a programme, nor do the economic benefits of the programme exhaust the complete range of benefits. Family planning programmes can be, and often are, justified without any reference to their economic benefits, but instead by reference to their contribution to the health and welfare of mothers and children, and their contribution to freedom of choice, particularly of women. There appears to be every reason why Ceylon should determine to build its national family planning programme over the next few years into one of the strongest in Asia. It is most unlikely that the relatively modest funds required would yield greater benefits in any alternative use." (Jones and Selvaratnam, November 1970).

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LECTURE TO SECTIONS C AND E

Lightning and the Electric Spark

by

T. E. ALLIBONE*

I must first thank you, Mr President, for inviting me to address a joint meeting of Sections C and E, and I will try to show the interplay between engineering and the physical sciences which has occurred throughout the history of the subject I have chosen. We can indeed begin with the "father of lightning research", Benjamin Franklin, who had been studying electrical phenomena in Philadelphia in the 1740's and had pointed out how similar lightning was to the electric fluid ; in as much as the discharge of a Leyden jar was attracted to a point, he said, lightning might also be so attracted, and he flew the famous kite to attract lightning. As the string became wet in a shower, sparks passed from the string to the condenser. (Please note, lest any member of the audience be tempted to repeat Franklin's experiment, that a Russian professor electrocuted himself by so doing!'). Franklin suggested that tall buildings should be protected from lightning by placing conductors high above them and the conductor carried down into the ground. Mr President, you as a Civil engineer will recall that this winter marks the bi-centenary of the Smeatonian Society of Civil Engineers, the foundation society of the institution of civil engineers. John Smeaton F.R.S., who was building the Eddystone lighthouse off Plymouth met Benjamin Franklin and possibly discussed with him the protection of buildings. Smeaton heard that the spire of Lostwithiel church had been damaged by lightning in 1757 and went to inspect the damage ; before the lighthouse was finished in 1759, he put a Franklin conductor on it leading straight down into the sea, one of the first applications of physics of lightning to civil engineering.

In the 1920's many high-voltage transmission lines were erected, particularly in America, and most of them were mounted on insulators suspended from steel towers, the tops of which were

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connected together with earthed conductors such that the "shielding angle" of this conductor to the highest of the line-conductors was about 30 degrees. Attention was paid to achieving the lowest resistance possible between the foot of the tower and earth ; in many terrains this might be a few ohms, but over desert country it was much higher. To measure the current in the lightning flash striking a tower small bundles of iron wire were placed on arms of various length projecting from the tower limbs and from the degree of remnant magnetism left in the iron after a lightning flash to one of the towers the maximum value of the current could be estimated. The general results of many investigations showed that flashes might carry currents of a few thousand amperes rising to infrequent currents of over 100,000 amperes, with a mean figure of 20,000 amps, and in 90% of all flashes a negative charge had been brought to earth. It was also found that the voltage on a line struck by a flash could rise to sparkover in a time of the order of a microsecond as a result of which test codes for the surge-testing of insulators and transformers called for the use of impulse voltages whose wave-front was to be one or one-and-a-half microseconds duration, and whose wave-tail should fall to half of the peak value in about 50 microseconds. The I.E.C. test code for such impulse voltages was brought in before the War.

Not much was known before 1930 about the physics of the lightning flash. Professor Boys had built a camera equipped with two lenses rotating at the opposite ends of a diameter and with this he intended to study the number of separate strokes composing a lightning flash. That some flashes were composed of many strokes had been known from photographic observations in the 19th century but information was meagre. Alas the frequency of lightning in England is so low that in many years Boys got only one record and that of no worth. Dr Schonland took that camera to South Africa and photographed many flashes in the Transvaal showing at once how very complex is the flash. In the first place he confirmed the multiple character of the flash ; some had as many as 20 component strokes, but the average number was about three per flash. Each stroke followed almost exactly over the ionised path of the previous stroke and the total time taken by a flash might amount to one second ; an observation many of you must have made merely by watching a good storm. But the most surprising discovery he and his team of research workers made was that every stroke was preceded by a discharge of low current value, or, better expressed, of low light intensity and he gave the name " leader stroke " to these components. Briefly, at the very beginning of a flash a leader stroke travels to ground from somewhere well within the thundercloud, and its velocity is about 10^7 cms per second, Its luminosity is low and it travels in jerks, or separate steps; so it was called a " stepped-leader stroke." On reaching the ground the luminous channel suddenly increases in brightness, the head of the wave of luminosity advancing to the cloud at great speed, 10^9 cms per second. This is called the " return stroke " and it is this component which carries the large current associated with the lightning flash. The current in the return stroke dies away in many microseconds in general either to zero or to low value and a hiatus occurs for about 1/10th of a second. Then another leader-stroke sets out from the cloud, this time travelling at about 10^8 cms per sec over the path blazed out by the first stepped-leader stroke. On reaching the ground this 'dart-leader' is followed by a return stroke of high current value as before. This process of dart-leader/main-stroke may be followed many times over the same ionised path till the charge centre in the cloud has been exhausted. There are many variations to the simple sequence I have described briefly but one result stood out, that 90% of all clouds discharged on the Rand had contained a negative charge.

In 1931 I had taken some photographs of discharges from a million-volt impulse generator using various forms of electrodes, point/plane, point/point, and point/pointed plane to study the branching of the electric spark to show Schonland that one of his deductions of lightning was in error. One of these photographs happened to record not only a main breakdown but also two partial discharges advancing from opposite electrodes towards one another. This was before Schonland had discovered the leader-stroke mechanism. But when in 1933 he published the first note about the leader concept I suggested to him that these partial flashes might be leader-strokes advancing towards one another but stopped in their tracks by the collapse of the voltage supply when the other main spark on the photograph had taken place. I set up a rotating camera and found that ahead of the main stroke at one million volts was a leader-stroke, and the main stroke followed exactly over the path taken by the leader, as far as it could be photographed. Together we published an account of the brief experiments and suggested the spark resembled lightning in this particular, a leader/main stroke sequence; what used to be the terminology for the lightning flash is now adopted widely for sparks. But there were marked differences ; in the laboratory the positive leader-stroke from point to plane traverses the whole gap whereas the negative leader-stroke from the high-voltage point is always met by an ascending positive leader-stroke rising out of the plane. If the plane electrode has any points sticking out of it these cause an enhancement of the upward positive-leader and if these points or one of them is very prominent the upward growing positive-leader will dominate the whole breakdown process ; from the Empire State Building in New York upward-growing lightning leader-strokes rise to the thundercloud. There has been a considerable interplay between the laboratory studies and the field observations on lightning for many years with mutual benefit to both.

Later work has established the importance of the corona discharge which precedes the leader-stroke from a high-voltage point electrode. The corona begins to form when the electric gradient at the point exceeds the critical gradient for ionisation of air, usually taken as 30 kv/c.m If the rate of rise of voltage at the point is very fast the gradient at a little distance from the point can rise correspondingly fast not much influenced by the space charge which takes a little time to form as ionisation proceeds outwards away from the point, and in these conditions the corona extends far from the electrode ; but if the rate of rise is low the development of corona is hindered by the space charge which of course modifies the electric field and lowers the gradient at the point electrode. After the corona has formed and the gradient at the electrode has been lowered in consequence, a little time elapses before the leader-stroke starts its journey towards the opposite electrode. If conditions are favourable it will cross the gap completely or be met by an ascending leader ; otherwise, its velocity of propagation will fall and eventually it will cease to progress and sparkover will not occur. It has been observed that the breakdown voltage of a gap falls as the wave-front of the applied impulse voltage is increased from say $\frac{1}{2}$ microsecond to say 100 microseconds, the fall being of the order of 10%, and after reaching a minimum spark-over voltage this rises as the wave-front is further lengthened. What I have said applies to the breakdown from a positive electrode ; the results on negative polarity are not so well defined ; the spread of results is so great that certainty has not been reached. The full facts of breakdown cannot be presented in this short version of the lecture but certainly there is as yet no complete understanding of the facts which have been accumulated.

Later work on lightning has also added to our knowledge. Professor Berger has photographed lightning striking a T. V. tower equipped with oscillographic recording apparatus, and the camera used was a rotating film camera, so well co-ordinated records of the flash and the electrical variations are available. He has shown that the current in the first leader-stroke to strike the mast does not rise to its maximum in a microsecond ; rather slower rates of rise were measured in the order of ten microseconds. But for subsequent dart-leader strokes the rate of rise is fast. Thus we now see that the oscillographers of years ago were right in quoting a rise time of a microsecond as typical, and therefore engineers were right in asking for impulse-voltage tests to be made with a one microsecond front-time ; what they did not know was that the first breakdown of the air-gap or over the insulator string had taken place when the lightning voltage at the gap was rising relatively slowly. So perhaps it would be better if impulse-voltage tests on insulators and across bushings were made with slowly rising wave-fronts to correspond more closely with the first stroke of the lightning flash: it should be noted, however, that inductive apparatus like a transformer winding must still be tested with the presently accepted fast impulse voltage because after the first stroke the dart-leader brings a fast rate of rise of voltage to the stricken point.

Another interesting interplay between spark records and lightning observations occurs in the matter of transmission-line routing for minimum line flashover due to lightning. As I have said, when a negative impulse is applied to a point/plane gap a positive leader stroke rises from the plane to meet the descending negative leader stroke and any point projection from the grounded plane enhances this upward leader. So a small point on the plane literally attracts the downward leader towards it and, moreover, it does so from a considerable distance laterally away from the straightest line joining the high-voltage point and plane. If the ground electrode has many projections from it then the leader-strokes rise haphazardly from each and all of them and one such leader manages to contact the downward descending leader. Now if a transmission line is traversing open country lightning will be attracted to it to some degree ; the conditions for being so attracted are rather complicated but are reasonably well authenticated. It is found that lines passing through a belt of trees are not so prone to lightning ; presumably the trees, like the many points on the plane are each providing an ionised path from their upper branches and one or other will meet the descending stepped-leader of the first stroke of the flash and then carry the whole flash to ground on that path. The result is that the line is, so to speak, merely one point contending with others to accept the leader stroke. If this observation can be well supported by evidence from other lines it clearly means that when cutting a path through trees for a new line the minimum width of cut should be made so that the line is protected to the utmost limit.

In this brief version I cannot quote the other examples of the knowledge derived from the one science being of assistance in understanding phenomena observed in the other science ; it is sufficient to say that the two have been complementary ever since Franklin's day and will almost certainly remain so.

LECTURE TO SECTION E

LASER AND LASER—INTERFEROMETER

by

M. BANTEL*

Introduction

The word 'Laser' is built by the beginning letters of "Light Amplification by Stimulated Emission of Radiation." A laser thus is nothing but a light source of special type. The light is produced as usual by atomic processes and then amplified.

1. Theory of the Atom :

To understand the principle of laser action it is necessary to look into the atom. We shall see that light behaves both as a wave and as a corpuscle. (A corpuscle of light is called a "Photon").

Niels Bohr in 1913 found that an atom consists of electrons revolving round the nucleus in orbits (Fig. 1). The electrons near the nucleus have low energy while those revolving in larger radii have higher energy. When a particle of energy collides with an atom, the electron from a low energy orbit may be transferred to a high energy orbit. Such an atom is called an "excited" atom. Two cases arise :

Spontaneous emission :

When the atom is left as such, the electron will fall back to its original orbit and a photon (light) will be emitted. The light from a neon sign lamp for example is emitted by this process.

Stimulated emission :

Here the photon produced by spontaneous emission beats out another photon from another atom. This new photon has the same energy and the same phase as the first photon. We thus have

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two coherent photons which help in beating out two more coherent photons from other excited atoms. This continues till we have a strong beam of coherent light.

A working laser, of course, requires some other devices, which we shall discuss in the following pages.

2. Laser Types :

Primarily we have two types of lasers ; solid state lasers and gas lasers. They are so named, because either a solid or a gaseous medium is used as laser active material. The atoms of this material give stimulated emission, when photons are striking them.

2.1 Solid State Lasers :

The solid material to be studied first for laser action was ruby. This ruby must contain a small percentage of chromium (about 0.05 percent). Ruby is the bearing material and chromium determines the frequency of the laser.

As we have seen above, an external source of energy is required to excite the atoms in the laser active material. (Fig. 2). In case of the ruby laser a flash light is used. An excited atom will fall back giving a spontaneous emission. A photon thus produced will strike another excited atom resulting in stimulated emission. This process will continue but unfortunately a strong emission cannot be built in this way. We get a strong light beam only by making the emitted photons to travel to and fro in the ruby rod. This can simply be done by putting two high efficiency reflectors on each side of the ruby rod. One of the reflectors has 100 per cent reflection while the other has a small transmission to allow the laser light to come out. A system like this forms a so called resonator.

The outcoming laser beam has a diameter of about 1 mm and is red in colour. The radiation is not continuous but it comes out in pulses. Against the pulsed radiation of this solid state laser, the gas laser has normally a continuous radiation.

2.2 Gas Lasers :

One gaseous laser medium studied is a mixture of helium and neon. This mixture is contained in a tube made of hard glass at a pressure of about 1 mm of mercury (Fig. 3).

The atoms in the gaseous mixture of helium and neon are excited by an electrical discharge through the medium. The helium atoms are excited first. The excited helium atoms collide with neon atoms exciting them. Only the neon atoms are responsible for laser action. Spontaneous emission takes place, which develops stimulated emission. It is just the same process as in the solid state laser.

The tube with the gaseous mixture is sealed with glass windows. The windows are inclined at the so called Brewster's angle to minimise the reflection losses. The tube is in between the two mirrors, which form the mentioned resonator.

The outcoming beam is about 1 mm in diameter and red in colour. The radiation is continuous but not so strong as that of a solid state laser.

3. Characteristics of Laser Light :

The laser is a special type of light source. So the characteristics of the laser light are best understood by comparing them with those of a conventional light source.

3.1 Parallelism :

An important property of laser light is its high degree of parallelsm. A beam of a good He-Ne laser for example has a divergence angle of only 2 seconds (Fig. 4). This means, that the diameter of the beam at a distance of 1 km will be about 10 mm and at a distance of 1000 km about 10 m. Against this a light beam from an usual bulb spreads out quickly in space and it is practically impossible to get a good parallel light even with the help of objectives and concave mirrors.

3.2 Power output :

The power output of a laser (especially of a pulsed laser) is unusually high. If we focus light from a solid state laser and from a 100 W bulb one after another on a one millimeter diameter spot, we find that the pulse of the solid laser is about 10,000 times stronger than the light taken from the bulb.

3.3 Monochromaticity :

High monochromaticity is another important feature of the laser light. High monochromatic light has a very narrow range of wavelength. We have some other ways also to get monochromatic light. We get it for example by spectral splitting of light from a normal bulb or by using a spectral light source. But unfortunately the light from such sources has very low energy. Further the obtained degree of monochromaticity is never as high as in the case of the laser.

3.4 Coherence length :

The coherence length is also a very important property of a light source and it gives the largest path difference between the two interfering beams obtained from the source such that an observable interference can take place between the two beams. The coherence length of the laser light is much larger compared with light from ordinary sources. The laser has a coherence length of more than 1000 km as against 5μ m (1μm $= \frac{1}{1000}$ mm) of a usual bulb and about 100 mm of a spectral lamp.

4. Application of Laser Light :

We shall discuss the application of laser light in terms of its characteristics, that is, parallelism, power output, monochromaticity and coherence length.

4.1 Parallel light :

This property of laser light can be used in the following applications :

Optical alignment : The laser light is very convenient for the alignment applications of an optical device. Since the laser has a narrow parallel beam it will pass through all the lenses without spreading too much. On the other hand the light from an ordinary source will spread out so quickly that it overfills some of the distant lenses. The laser beam can also be used for the alignment of mechnical devices such as bearings, railway lines, aeroplane wings etc. The straightness of long tunnels can be obtained with the help of an alignment set up. A number of factories are producing special gas lasers and attachment for these purposes.

Optical pointer : Again because of its parallelism light-pointers of several kilometers length can be obtained. This is to be used in the measuring field.

Measurement of distance : A distance measuring instrument using the laser looks like a double barrel gun. A laser pulse is shot out of one barrel which after reflection from the target enters the second barrel. The time between the leaving and the arriving pulse gives an indication of the distance of the object. The range of such an instrument however is limited by atmospheric absorption of light.

Signals in the outer space : The outer space is free from the atmosphere existing on earth. Here in the outer space clouds, fog, rain etc. do not disturb the light beam. Therefore the laser is a very convenient tool for measuring distances in the outer space. A good laser has in the outer space a range of more than 1000 km.

4.2 **Power output :** The high power output of a laser has been used for many industrial applications.

Drilling : When a laser light is focussed on a small spot the heat produced is so high that it is possible to get holes through metal plates several millimeters thick.

Welding : Similarly it is possible to weld small parts with a laser. We have a lot of such small parts in the electronic field, for example, transistors. As against the electron beam micro welding the laser welding needs no vacuum. This is a great advantage.

4.3 **Monochromaticity :** The high monochromaticity of the laser light makes it possible to focus the entire energy at a very small area, say, 10μm diameter (Fig. 5). This property allows micro drilling and micro-welding. It is only the monochromaticity of the laser light, which gives this advantage of getting with a lens a very sharp focus. In the case of an ordinary light source containing a range of wavelengths, the light is not concentrated at a sharp point. Different wavelengths have different focal planes and therefore we got not one but different focal points.

The monochromaticity of the laser light also makes it a very convenient light source for interferometry.

4.4 Coherence length :

This is the main property of the laser light when measuring length with an interferometer. What we mean by coherence length can easily be understood when we consider the working principle of the famous Michelson interferometer (Fig. 6). The monochromatic light coming from the source is divided into two parts at the dividing plate. One of the parts travels towards the fixed mirror M_1 while the other travels towards the movable mirror M_2. The beams will subsequently be reflected and reach the observer. Interference rings are observed when both mirrors are at equal distances from the beam dividing plate. If now mirror M_2 is displaced, the interference fringes also move. A mirror displacement of half a wavelength results in a movement of one fringe period. If the mirror M_2 is displaced some distance to the left or to the right, the interference fringe will disappear. The range of the good interference appearance is limited by the coherence length of the light sources.

By counting the passing interference fringes we measure the displacement of mirror M_2. This is the principle of all the interference length measuring methods. The possible displacement range is limited by the coherence length, which is extremely large for the laser light.

5. Laser-Interferometers

Different types of interferometers are available for the measurement of length. Basically all of them work on the principle of dividing and recombining a wave.

One of the laser-interferometers used in the machine tools shop is discussed. This instrument is used for precision displacement of the workpiece (Fig. 7). The laser-interferometer shown in Fig. 8 is a modification of the Michelson interferometer. A laser is used as a light source. The movable mirror is not a flat mirror but a so-called cube corner prism. This prism looks like a cut symmetric corner of a glass cube.

The cube corner prism has the property of sending back the incident light parallel to itself. This property is necessary to compensate for the tilting motion of the work table of the machine tool on which the prism is mounted.

When the work table together with the prism is moved, fringes also move across the field of view. When a bright fringe moves across a slit mounted in front of a photoelectric detector, an electric pulse is produced. The number of these pulses represents the displacement of the work table. These pulses are counted in an electronic digital unit.

This interferometer is able to distinguish between forward and backward motion of the work table. A temperature compensating device is inbuilt.

Laser interferometers are mainly used for machine tools with a very long displacement of the working table.

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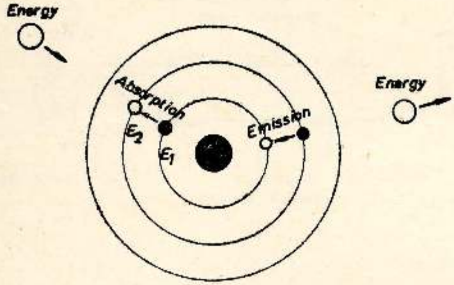

Fig. 1

ATOM MODEL AFTER NIELS BOHR (1913)

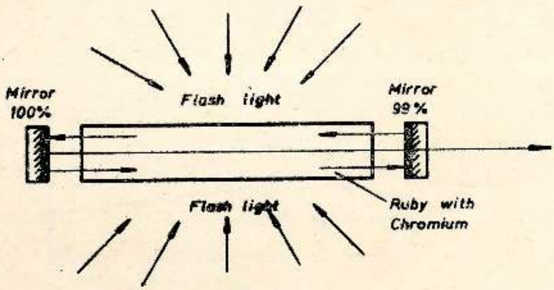

Fig. 2

PRINCIPLE OF SOLID STATE LASER

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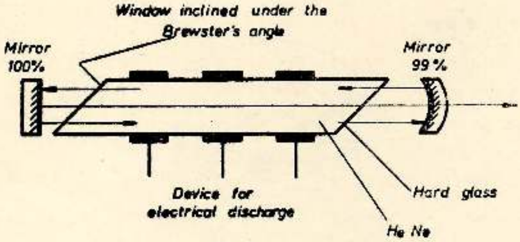

Fig. 3

PRINCIPLE OF GAS LASER

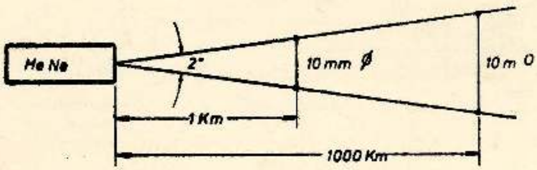

Fig. 4

"PARALLELISM" OF LASER LIGHT

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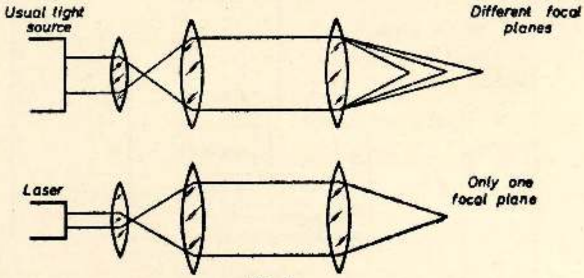

Fig. 5

"MONOCHROMATICITY" OF LASER LIGHT

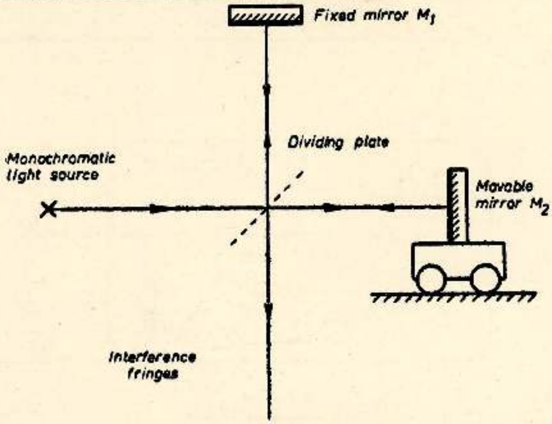

Fig. 6

PRINCIPLE OF THE MICHELSON INTERFEROMETER

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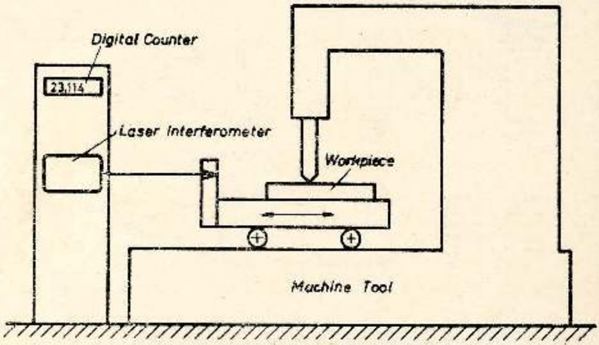


Fig. 7

MACHINE TOOL WITH LASER INTERFEROMETER AND DIGITAL DISPLAY

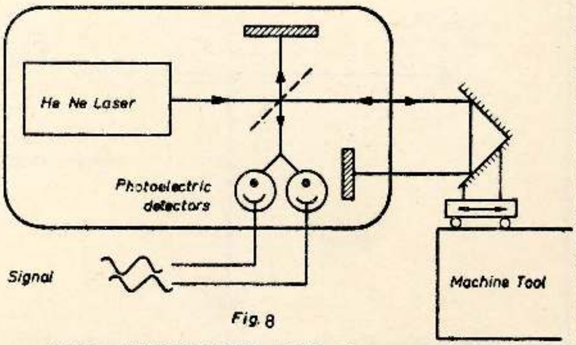


Fig. 8

LASER- INTERFEROMETER USED AT A MACHINE TOOL

DRN.	CHD.		DATE.

POPULAR LECTURE

POWER FOR THE YEAR 2000

by

T. E. ALLIBONE*

On Tuesday I brought you greetings from the old Mother of the Associations for Science and from that very old institution the Royal Society. Today your conference is over and I shall take back to England memories of a very successful meeting, and treasured memories of great kindness and hospitality shown to a foreigner. This kindness and hospitality seems to me to be in sharp contrast to the tone of some of the comments in the national press in which poor old England does not seem, in their eyes, to be able to do anything right. Well there will always be two sides to any problem and the one advantage England and Ceylon share in common is that our citizens are still free to criticise the government of the day, free to change that government by secret ballot, and they can walk about without fear from being overheard in conversation, and in fear of the security police. Long may this freedom remain. I am sure England wants to help Ceylon as much as possible ; the very name of the "Colombo Plan" derived from this desire, and in the Royal Society we have many arrangements for providing specialist help whenever we are asked.

Before I begin my address on this last day I would like to refer to some of the remarks we heard in that splendid first address, the one by the Minister, Mr Keuneman and I want especially to speak to the younger scientists here. You will recall that Mr Keuneman said that in choosing research projects the main criterion that should guide you should be the benefit likely to accrue to the economic development of the country if those projects were successful ; that consideration such as whether the subject chosen

*Representative of the British Association for the Advancement of Science.

is of current interest in the advanced countries, or is likely to lead to the publication of a paper in an international journal should not be the main ones. I agree wholeheartedly with those views but I want to give young research workers all the encouragement I can.I and many others have spent all our scientific life in industry. When I left Cambridge I went into one of the large electrical companies and all my research had to be aimed at improving the products manufactured or devising new ones. But if your work is successful you can almost certainly skim off the scientific cream of the work and publish it ; and I and many others from industry have been elected into the Royal Society solely on the basis of our published work. So do not regard Mr Keuneman's remarks as in any way derogatory to your scientific aspirations ; you can find, as I have found, great reward in industrial research and you don't have to go looking at moon dust.

You might think the year 2000 A.D. is along way off and that it is not necessary to give consideration to power requirements for that date yet ; strictly that is correct, a ten to fifteen year forecast of requirements is enough but in the heavy plant industry and in hydro-electric schemes the time-scale for realisation is so very long that it is worth trying to look ahead for more years than ten. All our power stations 30 years old are still in operation, some are nearly 50 years old and the big dams last longer than that unless they silt up. So I am going to reflect on those projects which are likely to mature and those which are likely to fade away. For the provision of electric power this thinking will be applicable to Ceylon as well as to other countries though the timing of new projects will differ in different countries. We have little water power, you have a lot and for your requirements hydro-electric schemes will probably provide you with all the power you can use for the next 20 years, even with a fast rate of growth of electric consumption but there is surely no time to waste in planning all the catchment areas capable of being used for power generation of say 20 to 30 times your present consumption. In England we might be generating 5 or 6 times our present consumption, so in Ceylon, if you are to reduce the gap between the developed and the undeveloped countries, you ought to be expanding at 3 or 4 times our rate.

One of the very satisfactory developments in the last ten years has been the pumped storage of water, that is the collection of water which has already fallen from a high dam and has generated electric power in so doing during the hours of daylight, and then, during the night when the demand for power has declined, using the generators as motors to drive the turbines backwards—so to speak—to pump the water up to the high dam. This operation can be done at high efficiency, so during the season of low rainfall or whenever there is inadequate rain to keep the top dam full enough, the hydro-electric generators can be kept in continuous use at a cost only fractionally greater than the cost of coal, oil, or nuclear generation, and the amortisation charges of the scheme can be spread over nearly all the hours of the year. We wish we had more sites for high level/low level dams in England ; you clearly have many, but they should all be scheduled now for development over the next decades. In saying this I am assuming that with your rainfall and your low labour costs hydro-electric schemes here are likely to be cheaper than any other way of generating electricity for a very long time.

At the first International Conference on the Peaceful Uses of Atomic Energy, at Geneva in 1955, Mr Eliezer of Ceylon gave the figures for electric consumption in 1954, 300 million units, and stated that some 14 big hydroelectric schemes could provide 500 MW of generation but that a further 23 could provide only 100 MW more ; 1000 MW appeared to be the very maximum that could be generated and not even that all the year round. With the pumped storage of water developed as far as can be in Ceylon it looks as though water power could carry you to the end of the century, but of course you need some other power to operate the turbines as motors and thus tide over the dry season and the droughts. He spoke then of the planned growth of many industries needing far more power than before but considered that nuclear power generation was very far off. Fifteen years have elapsed since then and we see the very satisfactory development of nuclear power in Britain. When you are trying to take long-term plans you can do so only on the basis of known technology and of known scientific facts still awaiting technological exploitation ; you cannot profitably consider speculative discoveries yet to be made. Thus my remarks have been made on the assumption that you have no oil or coal but in England in recent years we have discovered natural gas and recently oil in the North Sea. If you do the same in the next ten to twenty years nuclear generation might not be needed this century, but if you do not then I suspect your pumping power from nuclear generation will then be cheaper than power from imported coal or oil.

Before I discuss the role of nuclear power in Ceylon let me deal briefly with other possibilities. Supposing you were to rely to some extent on imported oil and/or coal ; what chances are there of improving the efficiency of generation of electricity over the next 30 years? The one big improvement we have obtained has come from the increase in size of the boiler and turbine, an increase in efficiency and a reduction of cost per unit generated. In Ceylon you will doubtless benefit a little from experience in the West; indeed we have paid heavily for our fast rate of growth, the big boilers, turbines and generators have all given more trouble than was ever expected. I saw in the press here complaints over the charges made by the West for electrical equipment but you are extremely fortunate in being so far behind us, because each ofthe unit types ought to have been well and truly tested in the West before you buy them and you ought to be spared from our expensive pioneering. But you cannot for a very long time reap the benefit of the largest sizes of generation,—so far the 500 MW machines in England, of the 1000 MW in America, certainly not in this century.

One very interesting old concept for improving the efficiency of energy conversion has received stimulus recently from an unexpected quarter; I refer to the so-called M.H.D. generation of electricity. In this a hot ionised flame passes down a duct in which electrodes are placed and across the duct is a very intense magnetic field. The ionised flame is an electric current, so placed in a cross magnetic field, is acted upon by a force at right angles to the current and the field. Power may therefore be drawn from the electrode placed in the duct. In former times the value of the power extracted could never reach the value of the power put into creating the magnetic field so M.H.D. rusticated. But some years ago metal alloys were discovered which retained the property of being superconductors at low temperatures even in the presence of a high magnetic field. So M.H.D. took on a new lease of life and in several countries research proceeded to make a duct which might give an extra 10% efficiency to the conversion from heat energy to electricity. The road is a long one and in England it became a cul-de-sac because nuclear energy appeared to be cheaper than a classical boiler/turbine preceded by an M.H.D. duct. But in countries where oil is cheap, work is still proceeding and the concept might become an established practice before the end of the century. By the time the flame has left the M.H.D. duct it is still hot enough to go direct to a boiler of the latest design from which overall efficiencies of nearly 37% can be obtained. Apart from the M.H.D. concept there is no other viable way of increasing efficiency except through an increase of pressure and/or temperature of the steam, possible only when new steels have been developed, and through small improvements all the way along the line of generation. Nor is there any viable alternative to the steam cycle for larger units of power. The gas turbine is widely used for smaller units but has not yet challenged the steam turbine for size or cost. Other thermal cycles using mercury and freon have been tried but neither has progressed far and the mercury has been dead for a long time. As the nuclear stations get cheaper,—as I suspect they will,—the task of devising better thermal cycles becomes less remunerative. So I am going to assume that there is no challenger for large power stations in the next 30 years.

In the field of nuclear technology rapid advances have been made along several parallel lines of development ; it is not easy to judge the relative merits of conflicting designs except when sales tenders have been submitted and that process has not been applied on a wide scale so far. The direction followed by Great Britain differs greatly from that followed by America and by Russia. At the moment Britain has by far the largest amount of installed nuclear generating capacity but America has by far the largest amount on order and being built, whilst Russia is well behind. Time only will show which of the various designs proves ultimately to become the cheapest, and even then, the conclusion may apply only to a particular size of station. Many of you must know the rough details of the various kinds of nuclear reactors. Historically, the Americans were first, using water as the coolant of the uranium fuel rods, and water also as the moderator of the neutron velocity.

Britain, beginning after the war, chose gas—carbon-dioxide gas—as the coolant and pure graphite as the moderator and both countries have persisted with their initial decisions.

The American designs all employ a thick-walled steel pressure vessel to withstand the pressure of the steam generated in the core of the reactor placed in the vessel. Either the steam is allowed to separate from the boiling water, in the so-called Boiling Water Reactor, the B.W.R., and the steam is passed direct to the turbine and condenser, or the steam is prevented from forming by maintaining an extremely high pressure, in the so-called Pressurised Water Reactor, the P.W.R., and the water is circulated through a heat-exchanger where steam is raised ; but the differences in these concepts are relatively small. Both result in steam of rather low temperature but the B.W.R. is remarkable in that very little radioactivity is carried over by the steam into the turbine and maintenance can be undertaken within a short time of closing down the station. I think there is greater safety hazard in this design compared with those which employ a heat exchanger between the reactor coolant and the turbine fluid but the penalty has not proved to be great and the B.W.R. looks as though it ought to be the cheaper design. Huge orders have been placed for both designs and it looks as though the designs will persist with only minor changes for at least another decade.

The British designs have changed considerably over the years and we have never had the benefit of mass-production of a single model. At first the coolant gas was contained under pressure in a 2″ steel vessel containing the reactor and the gas was taken to heat-exchangers outside the pressure vessel. Then the steel vessel was superceded by a concrete pressure vessel which acted also as the biological shield and the heat-exchangers were fitted snugly round the reactor inside the vessel. This generation of reactors used uranium metal fuel encased in a magnesium alloy container and all the reactors have given extremely good service and there is every expectation that they will last another 25 years or more. The cost of electrical generation is low compared with the cost of coal, ignoring the amortisation costs in making this comparison. The next generation of reactors is now being built ; in these reactors the fuel is oxide and is encased in stainless-steel cans so the operating temperature has been raised to that obtaining in the best fuel-fired boilers. The reactor and heat-exchangers are encased in the concrete pressure vessel as before and the present view is that the overall cost of generation including amortisation should fall below the costs of power from coal and also from oil because there is a tax on oil ; without this tax oil-fired boilers could contend for the lowest place in the cost table. However, none of these second-generation reactors are yet in operation, so I can only speak with caution about them. They are thought to be very safe and can be located near to centres of population, a very important consideration in our small island. I expect they will be in operation till well into the next century and I expect several more will be ordered during the present decade.

Beyond these two designs there are now two more contending for exploitation ; both have been designed by the Atomic Energy Authority and small versions of each have been in operation for a few years. One of them resembles the two British designs I have briefly described, in that the moderator is still graphite and the coolant is a gas, but instead of being carbon-dioxide it will be helium. This is of course a completely inert gas, so problems of corrosion ought to be avoided, but the gas is expensive and therefore the sealing of the vessel has to be done with far greater care and the cost of the vessel must surely be higher. Moreover, the fuel is no longer sealed in metal cans; it is in the form of small pellets the size of peas and each is encased in a silicate coating. If the coating is not perfect some fission products might escape into the coolant ; the total amount of this which can be allowed to escape to the atmosphere is very small. The heat-exchangers will be placed, as before, in the concrete pressure vessel though the shape suggested is different from those with which we have had experience. However the attraction lies in the fact that the overall concept is not so very different from those we have built and studied: it is thought to be a very safe reactor and now it remains to see what the cost will be. I suspect we shall be ordering one in the next few years and if all goes well this design might last us for a decade or two.

The alternative design prepared by the A.E.A. is quite different and therein lies its weakness. It is a water-cooled reactor and the moderator is " heavy water " instead of graphite. The coolant is confined in pressure tubes in which the fuel elements are placed in cluster formation and the pressure is such that the water is allowed to boil as it passes over the fuel, hence the name for this design the "Steam Generating Heavy Water Reactor, "S.G.H.W." The pressure tubes are insulated from the heavy-water moderator, the temperature of which is therefore low and the vessel containing it is at atmospheric pressure, thus avoiding the hazards associated with the huge thick-walled American pressure vessels. The reactor which has been built has provided 100 MW of power for a long time satisfactorily but I cannot say which of the two types I have described briefly will be chosen for massive development. It is in a sense unfortunate that the A.E.A. has served up two magnificent meals at the same time; they cannot both be digested and the development costs of one of them may yet be wasted.

One interesting feature of both reactors is that they could both be adapted to the thorium cycle in due course, I mean by the time Ceylon is needing nuclear reactors, say in the 1990's. They will by then be well-tried reactors and their capital costs and running costs will be well established. There are huge local reserves of thorium and India's metallurgical industry should by then be capable of supplying all your fuel needs.

I ought to mention, again only briefly, one other reactor which will be of extreme importance to the world before the end of the century but which is hardly likely to feature in Ceylon's power industry till well into the third millenium. I refer to the so-called " fast reactor." so called because it uses no moderator to slow down the neutrons, produces fission whilst travelling at very high speed, and also converts a blanket of ordinary uranium into plutonium whilst travelling with high velocity. The overall result of this design is that the reactor can " breed " more plutonium than the amount of uranium which undergoes fission. All the large power reactors now operating in the world burn up the light isotope of uranium, the U.235 and only a very small amount of the abundant heavy isotope, U. 238. At present there is no shortage of the light isotope, that is of cheap uranium ore, but by the end of the present century the cheap supplies will have been used up. There will be huge dumps of the discarded U. 238, not unlike the coal slag dumps of South Wales (not such huge mounds of course) and without the advent of the fast reactor these would be valueless. But if the fast reactor operates successfully and safely then all this uranium can be used and will outlast the next century. There are several small fast reactors in operation and some larger ones are being built to provide operating experience and from which realist assessments of costs can be obtained. They present formidable problems but engineers seem to be meeting the challenge and later in the present decade I expect fully commercial reactors will be under construction. By 1990 we ought to know whether the large-scale breeding of fissile fuel is commercially viable ; if it is there will be no shortage of fuel for a very long time and in the last decade of the century very many such reactors would be built. By then probably three-quarters of Britain's power would be generated from nuclear fuel, the rest from oil and coal ;—but, as I said before, the distant forecast can only be guess-work.

I have drawn only the outlines of a picture ; it would take too long to fill in the details and the time would be partly wasted because of the uncertainties I have mentioned. But I have said enough to indicate that for countries without water power the coming of nuclear power is most opportune. Our own country is short of coal ; we have,—so far—to import all our oil so that we are at the mercy of Midlde Eastern politics and in the long run we shall all need uranium when oil has run out. The internal-combustion engine seems to be doomed because of the pollution it creates in our cities and if the electric battery can be greatly improved in the coming decade cars may all switch to electricity. You here are most fortunately placed, gaining the best of two worlds so to speak. You have ample water-power for the present and future needs for say 20 years, with pumped-storage the time scale can be further expanded and then by the time you need more power for the pumps nuclear reactors will have been in use on a colossal scale in the developed countries of the world. The great advantage of the British designs of reactors is that in foreign countries they could be built largely with indigenous labour but I cannot see a country like Ceylon making the American pressure vessel for a very long time : they would have to be imported.

We are about to celebrate the centenary of Lord Rutherford's birth. He came from New Zealand as a young man with a scholarship to Cambridge and in the short space of twenty years gave us a new Science, laid the foundations for a new industry, and set the pattern for a new age. He established the radioactive transformations from uranium to lead, he identified and named the disintegration products, the alpha and the beta-particles and the gamma-rays, he proved that the atom consisted of a small central nucleus surrounded by a cloud of electrons, he measured the size of the nucleus and deduced the forces holding the component parts together and then he disintegrated nuclei of some of the ligher elements using the alpha-particles from radium and in so doing unlocked some of the energy stored in the nucleus, an energy, per atom, a million times greater than the energy released when two atoms unite chemically. He forecast the existence of the neutron as a component of nuclei-though they were not discovered for another 13 years in his laboratory, the Cavendish in Cambridge. He forecast the possible existence of the " heavy hydrogen and indeed was the first to use this 15 years later to effect the distintegration of other elements. Within ten years of his death nuclear disintegration had been used to end the war and to provide huge amounts of thermal power, and now twenty-five years after his death we see in nuclear disintegration the hope of the world for keeping the peace and for providing us with power ; he, surely more than any man, will be regarded as the father of nuclear energy just as Michael Faraday is regarded as the father of electricity.

LECTURE TO SECTION F

TECHNICAL EDUCATION IN WESTERN GERMANY

by

M. Bantel

1. Home Education

A main feature of the technical education of a German is, that it starts not just in the University, but in early childhood. The child tries to build houses, bridges, towers etc. with the help of bricks. In doing so he gets the feeling for effort and success. Through his failures he learns to struggle and realises the necessity of systematic approach. As he advances in his age, he plays with toy cars, toy buses and learns about motors, steering wheel and car types. With the help of unitized systems (wooden and metallic) he builds wind mills, sewing machines or tractors and learns in the process to handle lever systems, gear wheels, screws and nuts. He also makes use of tools like the hammer, drill and saw. In addition, almost all German children play with automatic controlled electric model trains, planes or ships. Besides these activities within the four walls, he has a bicycle and later on perhaps a moped or a scooter for outside use. When something goes wrong he tries to repair these items himself. All such activities help him in grasping some basic laws of science and in molding his brain towards technology. It is this technical education at home, with which a German starts his technical education in school and university.

2. School Education

A German enters primary school at the age of six years. The primary schooling is covered in four years. Then he enters a secondary school which enables him to study in any university afterwards. The secondary schooling is spread over a period of 9 years. Here he gets on the technical side fundamental lessons in mathematics, physics and chemistry. At the time of passing the final examination he is 18 years old.

3. **Industrial Training**

Before entering a technical university he has to undergo a half year's practical training in industry. The programme of this training is prescribed by the university. During this period he learns all basic workshop processess such as filing, drilling, turning, milling, shaping, casting and forging. Six more months have to be spent for practical training during the university holidays. This one year training is of great importance for the student in his studies and later on in his profession. In addition to this practical training, every student gets at least 20 opportunities to participate in university organised excursions to factories.

4. **University Education**

In the university there is a definite emphasis on the practical side, which will be discussed with the example of mechanical engineering. There are a number of laboratory experiments in mechanics and physics. There are also some elective experiments in instrumentation, or any other field. These experiments are built to call in the personal practical engagement of the student.

In the university lectures, stress is laid both on theory and applications. In this connection it might be mentioned that a student working for Ph. D. degree or for any other project starts with the relevant theory and after completing it to a certain level he starts with the experiment. This provides the right type of relationship between theory and experiment.

The courses in the university start with the fundamentals in mathematics, physics, chemistry, mechanics and geometry, design, machine elements and strength of materials. In addition subjects such as management, law and economics have to be studied by all. In mathematics, physics, mechanics and geometry, there are tutorials in which practical problems are explained and solved. Similar problems have to be solved by the students and to be submitted for correction and evaluation.

After 2 to 3 years (4 to 6 semesters) the student has to take about 10 examinations, known as prefinal examinations, in the subjects taught. The next 4 to 6 semesters lead to a certain degree of specialisation. Examinations are conducted in about 10 subjects which together form the final examination.

The examinations in the German universities are usually not held immediately after the courses but towards the end of the holidays. This helps the students to make use of the holidays to prepare for the examination.

Apart from these examinations the student has to work on 2 design projects, such as a motor or a turbine. In addition he has to work on the 'Diplom-thesis' which may be a design or experimental or purely theoretical. A successful completion of the examinations and projects makes him eligible for the degree of 'Diplom-Ingenieur' (Dipl.—Ing.). The student is now about 24 years old.

5. University Freedom

The German university offers a certain degree of freedom to its students in the selection of subjects and laboratory experiments. The student is free to attend or not to attend the lectures. The examinations, however, are compulsory. A self discipline is imposed by the students themselves which works fairly well. This freedom inculcates a sense of responsibility in the student and brings forth his initiative and ability for independent working.

6. Polytechnic

This is the second stream of technical education in Germany. The first 4 years of primary education are common in both streams. The primary schooling is followed by 5 years of 'main schooling'. Compared to the three foreign languages in the secondary school the 'main schooling' has only one compulsory foreign language. The courses given in mathematics, physics and chemistry are less extensive. After the 'main schooling' the student has to go in for 3 years of apprenticeship training in industry. Once per week he attends lectures in a technical school. The apprenticeship training is followed by a 3 year course in a polytechnic. After completing the curriculum he gets the degree of a 'graduated ingenieur' (Ing. grad.).

7. Polytechnic and University

The difference between the polytechnic and university education may be seen as follows :

In the polytechnic apart from getting the basic courses, the student learns to solve typical practical problems. He can then solve similar problems in his professional work. Besides because of his intensive industrial training he is often superior in tackling practical problems.

In the university more emphasis is laid on the theory, so that this student can solve problems which call for creative thinking. These effects are already there within the studies and they become still more clear in the profession afterwards.

8. Professional Bodies

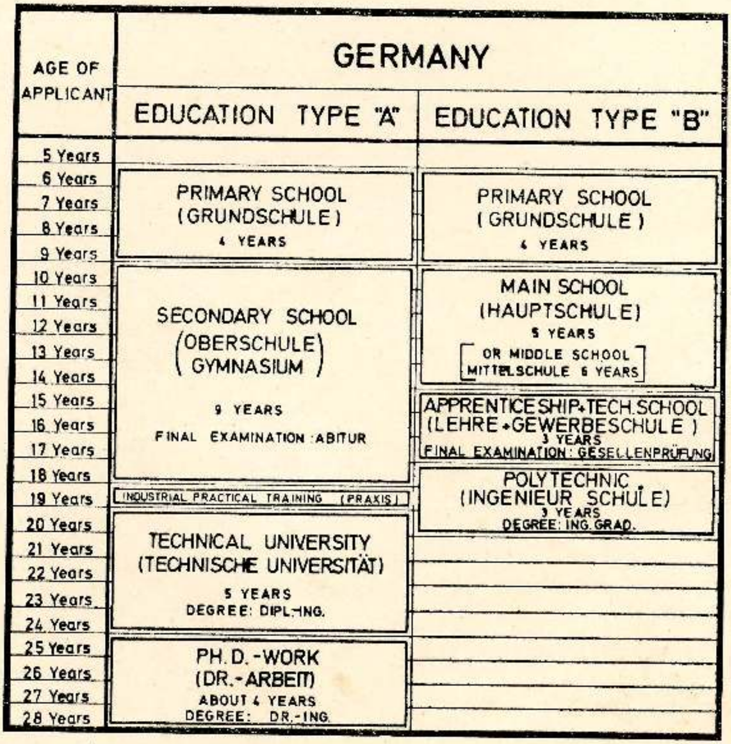
The professional bodies influencing the technical education in Germany are mainly sponsored by the Government. Industry and private bodies are also involved, but they are confined only to special research work.

For the research as a total the ' ministry of science and research ' is mainly responsible. The ' ministry of education ' takes care of technical and non-technical education in primary and secondary schools, polytechnics and universities.

The ' German research association (DFG) ' supports special research of academic character. It is financed mainly by the Government. The ' working group industry and research (AIF) ' supports research projects which are of immediate industrial importance. This group gets its finances from the member industries and firms. Recently the AIF has joined the DFG.

The ' Duisberg association ' finances the polytechnics and technical schools. Some private foundations are also supporting the technical research.

The conference of the Directors includes all the Directors of the German universities. They meet once a year to decide on the university matters.


AGE OF APPLICANT
GERMANY
EDUCATION TYPE "A"
EDUCATION TYPE "B"
5 Years
6 Years
7 Years
8 Years
9 Years
10 Years
11 Years
12 Years
13 Years
14 Years
15 Years
16 Years
17 Years
18 Years
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20 Years
21 Years
22 Years
23 Years
24 Years
25 Years
26 Years
27 Years
28 Years
PRIMARY SCHOOL (GRUNDSCHULE) 4 YEARS
SECONDARY SCHOOL (OBERSCHULE GYMNASIUM) 9 YEARS FINAL EXAMINATION: ABITUR
INDUSTRIAL PRACTICAL TRAINING (PRAXIS)
TECHNICAL UNIVERSITY (TECHNISCHE UNIVERSITÄT) 5 YEARS DEGREE: DIPL.-ING.
PH. D. -WORK (DR.-ARBEIT) ABOUT 4 YEARS DEGREE: DR.-ING.
PRIMARY SCHOOL (GRUNDSCHULE) 4 YEARS
MAIN SCHOOL (HAUPTSCHULE) 5 YEARS
OR MIDDLE SCHOOL MITTELSCHULE 6 YEARS
APPRENTICESHIP+TECH.SCHOOL (LEHRE+GEWERBESCHULE) 3 YEARS
FINAL EXAMINATION: GESELLENPRÜFUNG
POLYTECHNIC (INGENIEUR SCHULE) 3 YEARS DEGREE: ING. GRAD.

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