CEYLON ASSOCIATION

FOR THE

ADVANCEMENT OF SCIENCE

PART II

PROCEEDINGS

OF THE

NINETEENTH ANNUAL SESSION

20th to 23rd November 1963

COLOMBO 1964

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CONTENTS — PART II

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1959—1

NINETEENTH ANNUAL SESSION
of
The Ceylon Association for the Advancement of Science
Wednesday, 20th November, 1963

Opening Address

by

HON. MRS. SIRIMAVO BANDARANAIKE,
PRIME MINISTER

Mr. President, Ladies and Gentlemen,

I am very grateful to the Council of the Ceylon Association for the Advancement of Science for the invitation to me to declare open the Nineteenth Annual Session of your Association.

I r ust confess at the outset that I speak to you this morning with a certain amount of trepidation. I am not a scientist, although I have a profound respect for Science, and my acquaintance with the laboratory and the other paraphernalia with which scientists usually work, ended with my leaving school. Science to me is therefore, something of a mystery and I share the average layman's sense of bewilderment when I am confronted with the spectacular achievements of scientists. I shall, therefore, not attempt to speak on Science but on the much more general idea of what I think should be the role of the scientist in a developing country such as ours. I assume that your invitation to me, as Prime Minister, to open this Conference is your method of expressing your view that Science and Scientific Research is of primary significance to our country. My acceptance of your invitation will, in itself, indicate to you the fact that I rate your work as of the greatest importance.

Never before in our history as a nation have we needed the enthusiastic and dedicated labours of the skills such as this audience represents. In your Association, are found scientists belonging to several allied disciplines. Medical men, engineers, physicists, biologists, economists, agriculturists and social scientists. The expert knowledge that you possess is, I know clamouring to be harnessed and channelled into productive use. At the same time, there is in the country a widespread desire for the new learning and techniques which you can give. We are experiencing a revolution in attitudes and in the minds of people, consequent on the social and economic changes the Government has introduced, and there is a real thirst for the new knowledge that you possess. The field appears, therefore, to be wide open for fruitful work by the scientists of this country and I have no doubt that you would be equal to the demands that your country will make of you.

We are now committed unrelentingly to a policy of planned development. We cannot afford the luxury of the hit-or-miss methods of the past. Planning is an imperative cast on us by the circumstances in which we find ourselves, and I am sure that there is not one among us who can have any doubt on that point. What we have now to bend all our energies to, is the task of increasing production in agriculture, both in our export crops of tea, rubber and coconut, and in cultivation of rice, as well as in Industry. There can also be no doubt in our minds about the need to embark on industrialisation at the fastest possible speed. Indeed, fair success has already been achieved in this direction. Sometimes, I have heard the view expressed that we should concentrate on the production of agricultural commodities for which we seem to be especially blessed by nature. The argument runs that once we have achieved self-sufficiency in rice, we would be able to make use of the export surpluses we obtain from the sale of our tea, rubber and coconut products in world markets to buy from abroad all our other needs. But this is a very simplified and incorrect assessment of the picture. We hold the view that industrialisation is and imperative because it goes hand-in-hand with the development of agriculture. They are inter-dependent and interwoven. Agriculture must get from Industry, equipment, machinery like tractors, fertilisers, and sources of power. Moreover, our growing population cannot be absorbed in fruitful employment on the land. Like in the industrial West, more and more people are today moving away from occupation on the land, and will have to be employed in manufacturing industries. In this great adventure of industrialisation on which we are now launched, you, the scientists and technologists have a vital role to play. We need your help in the attempts we are making to eliminate poverty and want. We want to give our people a sufficiency of food, housing and clothing, so that the achievement of these basic needs may cease to be the sole objective of their existence and the people's energies may be liberated to the development of their culture and the full flowering of their personalities.

And that brings to my mind another aspect of your place in society as scientists. It is an often stated and widely held belief that science and values, call it religion, call it culture, are incompatible. Perhaps this has grown from the stand which Science has taken, as being amoral and as being only concerned with the discovery of what works. In part, this view has been reinforced in people's minds by certain lamentable trends in modern society that we can see developing. We have seen how with the growth of Science

and Industry there is a falling away in moral standards and spirituality. We see, too, the manner in which each advance of Science appears to take us ever closer to the destruction of mankind. Through Science we appear to have created machines which now control Man. Humanity is now troubled by fear and suspicion and we have gone further and further away from the ideals of loving kindness, tolerance and brotherhood, which all religions proclaim. A question, I am sure, which all of you have asked yourselves, as most ordinary people do, is whether there is not any way of harmonising these differences, these apparent contradictions which exist. A scientist is, after all, also a human being. He too has a view of the world in which he and his children would like to live in, and if he does not forget his essential humanity or humanism there is hope for the world. Particularly through a branch of the Sciences which I know has only recently assumed a status of respectability, namely, the social sciences, there may be a key to the settlement of the problem I just referred to. I see that your Association has honoured the social sciences by making one of its kind your President-elect—I believe for the first time in your history. This, perhaps, is an indication of the importance your members ascribe to the part that the social sciences too can play in the solution of the urgent and pressing social problems that we are confronted with in this country. One of your major tasks as scientists, would be to examine the means by which, in a period of rapid social change and industrialisation, we can still keep the best of the rich cultural and spiritual heritage to which we are heirs. The challenge we have to face is whether we cannot have technology and Science, and the amenities which they can give us, along with those other basic values which are the pre-conditions for civilized life as we know it.

In Ceylon, unlike in some Western countries, where scientists are derisively referred to as "egg-heads", the intellectual or the man with creative ideas, has always held an honoured place. There is a great respect—sometimes, I feel, a too great respect—to the purely academic, to the pundit, or guru and too little to the technician and the man who works with his hands. However, this high status that you hold in society gives you an excellent opportunity for influencing events, and to be a real driving force in the life of this country. To speak frankly, it has often been said that the scholar in Ceylon is too apt to tie himself up in his own particular field of research, in his closeted study and keep out of the main currents of life. Conversely, the Government often hears the accusation that the advice of experts is disregarded and goes unheeded. Perhaps there is some truth in both these positions. But the time for apportioning blame appears to be now past, for the present demands are too insistent to warrant any debate on such matters. What we need now is the active co-operation and partnership of all who have the interests of the country at heart. I would like to, therefore, make an appeal to you, as Prime Minister, to come forward with your ideas and the results of your labours so that they might be effectively used in the service of our people. For its part, the Government has accepted the need for the formation of a national body with the necessary authority to guide scientific activity, on the lines that many other countries have adopted with such profit to themselves. In India, there has been a Council of Scientific and Industrial Research for many years. Here, we have unfortunately had no such body to co-ordinate scientific activity and to make the maximum use of the available scientific personnel. This, I have no doubt, is one of the reasons why the scientists of this country have lacked the feeling that they are part of a great national effort. I am glad to announce on this occasion that the Government holds the view that a body such as the National Research Council, which has been proposed for Ceylon by your Association, is most essential, and the necessary steps will be taken to constitute such a body as early as possible.

I thank you once again for the opportunity you have given me of addressing you and of offering these comments for your consideration. I should also like to take the opportunity of congratulating your Association on its past work. I hope your Nineteenth Annual Session will prove fruitful and rewarding. I wish your Association every success in the development of the work it is engaged in.

I have now great pleasure in declaring open the Nineteenth Annual Session of the Ceylon Association for the Advancement of Science.

General President's Address
20th November, 1963

PLANNED ECONOMIC DEVELOPMENT

by

W. T. I. ALAGARATNAM

Hon. the Prime Minister, Hon. Dr. Rao, Hon. Ministers, your Excellencies, distinguished guests, friends and colleagues.

As this happens to be the first occasion on which I am addressing you since I was elected General President, I take this opportunity of thanking the Association sincerely, for the honour and responsibility they have placed on me, and the profession to which I belong. When I consider my illustrious predecessors in office, I feel rather diffident and unworthy of the honour. However, with the able assistance of the indefatigable Honorary Secretaries, and the help and co-operation of the Council, we have come to a satisfactory conclusion of another year, and completed 19 years of existence, one year more than the age at which the youth of Ceylon gets the franchise, and becomes eligible to vote for what he or she wants the future of our country to be. We cannot help the past or alter the past. What has been done or left undone has to be accepted. But the future is in our hands and is dependent on our present action or inaction. What we are going to achieve depends on what our plans are, and whether we are prepared to carry out our plans and are ready to make sacrifices that may be necessary to carry out our plans and programme.

Objects of the Association

As you may know, the objects of the Ceylon Association for the Advancement of Science are :—

(1) to promote the advancement of Science (Pure and Applied)
(2) to provide for systematic direction of scientific enquiry, in the interests of the country
(3) to promote contact between scientific workers
(4) to hold annual sessions, and
(5) to disseminate scientific knowledge.

To facilitate study and discussions, we have six sections corresponding to the main branches of science :—

(A) Medical and Veterinary Sciences (B) Agriculture and Forestry (C) Engineering (D) Natural Sciences (E) Physical Sciences and (F) Social Sciences.

Apart from special meetings held during the course of the year, to hear eminent scientists who happen to visit our Island, and the symposia held by the different Sections of the Association, we meet annually at our General Meetings, where papers on scientific subjects are read and discussed. We also have the privilege of listening to guest lecturers invited to the sessions, scientists who are eminent in their fields.

Special attention is being given by the Association to popularise science amongst the masses. With the advancement of science, it has become necessary for even the common man, to be acquainted with the rudiments of science and its day to day applications. Ignorance of science, or its misuse may cause disastrous results.

Last year donations made anonymously totalling Rs. 11,000 have been received for the purpose of popularisation of science. One of these donors has made arrangements to donate Rs. 10,000 each year to the Association to be used for this very important purpose. This year a further sum of Rs. 5,000 given by another anonymous person has been received. We offer our deepest thanks to all these donors and I can assure them that their money is being put to the best possible use.

Our grateful thanks are due to the Asia Foundation for the munificent grant of Rs. 218,000 for the School Biology Curriculum Revision Project.

Research is necessary for any advancement, and the importance of research for the scientific, industrial and agricultural development of a country, is admitted by all, and is given prominence, in all developing countries.

In spite of the meagre facilities available in this country for research, some work is being done in the different technical departments of the Government, and also by private agencies, in connection with their technical work. But because there is no central co-ordinating authority, there is, as would be expected, considerable overlapping. The progress and achievements of these scientists are not published for the benefit of other research workers and the general public. To remedy this, the Ceylon Association for the Advancement of Science has proposed the setting up of a National Research Council. To be an authoritative body, this Council should have the recognition of Government. The formation of the Research Council, awaits the consideration of Government, and it is hoped that the agitation of the C.A.A.S. for the last twelve years, will soon bear fruit.

Development of Irrigation in the Country

Having been associated with irrigation in this country for over four decades, it is appropriate that I should devote most of my address to Irrigation, and Planning for the development of Irrigation in this country, and I hope you will excuse me for doing so.

Irrigation is as old as civilisation, and Ceylon can justifiably be proud, of her achievements in this sphere in the past. Parakrama Bahu the Great, one of Lanka's illustrious rulers, had given the dictum that "not even a little water that comes from the rain must flow to the ocean, without being made useful to man". True to this command, you see the Island dotted with numerous irrigation works—tanks, anicuts and channels—for conserving rain water, and diverting it for irrigation and domestic use. Though most of these works are very small, some are of medium size, even by modern standards. The ingenuity displayed, in the location and construction of these irrigation works, is admitted even by modern engineers. However, the existence of these works has made the work of the modern Engineer more difficult, in that he tries to integrate them into his scheme of development, so that the large amount of earth-work and labour spent on them, may not go waste. A good portion of these works which have gone into disrepair, due to several causes still remain in a breached condition. Sporadic restoration of some of these schemes was taken up during the sovereignty of the Dutch and the British. But with the establishment of the Irrigation Department in 1901, more attention was paid to these tanks. Villagers were allowed to restore some of the smaller tanks contributing free manual labour, for the entire jungle clearing and earth-work necessary. In return for their labour, the villagers were given land, under these tanks, for cultivation. But this was a very slow process, as the villagers were very poor and incapacitated by malaria and other diseases to make any sustained effort. Government undertook the restoration of some of the bigger tanks, when there was persistent agitation by the villagers and by the Revenue Officers for the restoration of these tanks to relieve distress in the area. But schemes of restoration were taken up only when there was a guarantee of adequate return for the expenditure. With the introduction of Local Self Government, District Agricultural Committees were set up, which were empowered to prepare lists of irrigation schemes, to be taken up for restoration or improvement by the Irrigation Department. The schemes put up by the District Agricultural Committees, were investigated by the technical staff of the Irrigation Department, and if they were found feasible were taken up for construction, on the Village Works Improvements Vote. Under this system, a large number of village irrigation works were improved in the Dry Zone of the Island. In 1948 the Gal Oya Multipurpose Reservoir Project was started to provide irrigation for 120,000 acres, produce 10,000 kilowatts of hydro-electric power, and afford flood protection for about 20,000 acres of low lying fields. The reservoir was completed in 1951, and the development is expected to be completed this year. But generally schemes were taken up, *ad hoc*, without any planning, on a river catchment basis. The result was that some of the schemes became redundant or they adversely affected the future development of the basins.

Water Resources of the Country

Though river gaugings and rainfall records were kept for several years, it was only in 1952 that a systematic study of the water resources of the country on a catchment basis, was taken up and by 1958, a plan showing the tentative proposals for the development of the water resources of the Island was prepared. The plan indicated possible reservoir sites, irrigable areas, reafforestation areas, forest reserves, wild life sanctuaries etc.

The area of Ceylon is about 25,000 sq. miles with a mean annual rainfall of about 75″ giving a run off of about 25 million ac. ft. But the rainfall is not uniform over the whole Island nor is it uniformly distributed throughout the year.

The surface area of Ceylon falls into two zones, the wet zone, having an area of 2.9 million acres, and the dry zone, having an area of 11.6 million acres. The wet zone has the advantage of the two monsoons, the North-East and the South-West, with an annual rainfall of about 75″ to 200″. The dry zone has the benefit of only the North-East monsoon, with a rainfall of about 25 to 75 inches.

As the incidence and intensity of rainfall is unpredictable, and is confined to four months of the year, the necessity for impounding water, for the successful cultivation of the land, especially in the dry zone is obvious. These reservoirs, will also help to reduce flooding of the low lying irrigable areas.

The dry zone has the larger potential irrigable area. Most of the cultivable land in the wet zone, is developed under the economic crops of tea, rubber and coconut, with patches of paddy only in the valleys. The area to be developed for agricultural purposes, is therefore mostly in the dry zone. The storage proposed to be utilised according to preliminary calculations is about 9,000,000 ac. ft. for irrigating about 1,500,000 acres in paddy, which is the staple food of the people. It is also estimated that over a million kilowatts of hydro power will be available by tapping the rivers and streams of the hill country.

It is questionable whether all the irrigable land should be cultivated with paddy for the country to be self sufficient in its staple food; especially when the guaranteed local price of paddy is about double the world price. Will it not be more economical to grow subsidiary food crops which require less water and also to increase the cultivation of more economic crops?

With the aid of the Canadian Air Survey maps, and the field investigations of the Agricultural Department a soil utilisation map of the Island is under preparation. This map is expected to indicate the most economical crops to be grown in different parts of the Island.

In the past all irrigable land had been put under paddy but a change has been introduced in Gal Oya and Kantalai, where about 20,000 acres are being brought under sugar cane. It is proposed under the Uda Walawe Scheme to still further diversify cultivation under irrigation according to the suitability of the soil. Areas have been demarcated for paddy, sugar cane, citrus, cotton and ground nut.

Rate of Development

The rate of development under irrigation schemes has been rather slow in the past. During the early days when malaria was rampant and there was no Government aid for development it took several years for the land to be asswuddumised. With the eradication of malaria and the introduction of colonisation schemes, the position improved to some extent. The land was either fully developed before the colonist was settled on it, or he was given monetary assistance to develop the land. But even this has not been satisfactory or economical, as will be seen from the development in the Gal Oya Scheme. Here, it had taken 12 years to fully develop the area under the command of the reservoir which had already been constructed. This meant that several millions of rupees spent on the construction of the head works, were unprofitably blocked without producing any return.

It is proposed to remedy this in the Uda Walawe Project where it is programmed to complete the construction of the channels and have the land ready for cultivation simultaneously with the completion of the head works.

In a country with a short supply of technical men, skilled labour and heavy construction machinery, the wisdom of concentrating on fewer schemes, and bringing them to fruition is quickly as possible cannot be overemphasised. By prolonging the work, not only are the staff and labour dissipated and not fully employed but also the expenditure on camp construction and maintenance, flood damage repairs, incidental expenses and contingencies are increased out of proportion to the original estimated cost of the scheme. As a result of this frequent revisions of the estimates become necessary.

Investigation and Planning

Before any development work is started thorough investigation should be made and sufficient data collected for proper planning and programming the construction. Target dates should be fixed for the completion of each item of work. The goal should be always kept in view. When there is no definite goal to work to, procrastination and delay are bound to occur. It cannot be assumed, that once the work is properly started, it will look after itself. Work with proper planning is well begun. Though "Well begun is half done", sustained effort is necessary to keep to programme. Rate of progress should also increase with experience. The oft repeated excuse that the cost of an item of work has increased because of the annual increments of pay to the staff and labour is not always acceptable. With experience, one should find ways and means of cutting down cost by more detailed planning and improved methods of construction. Just as you cannot build a house without a plan a country also cannot develop without a plan. It is easy to destroy without a plan, but if you try to build up and develop without a plan the result may be chaos.

It is because planning is vital for progressive development that the progressive countries have their 5 year, 10 year and 15 year plans to which they give top priority.

Though Ceylon obtained its political freedom in 1947, it has not yet achieved the other freedoms, dependent on the economic development of the country. Like most of the other newly independent countries, it is still underdeveloped in that its natural resources are not sufficiently exploited, to benefit the people and increase their standard of living.

When a country which has been under colonial rule gets political independence, there is usually an urge for rapid economic development from a backward agricultural country to a highly industrialised one. Agricultural development is determined by the land available for cultivation which is limited. But industrial development which can employ the increasing population is cumulative and is self propagating provided we choose the correct industries. Political freedom without economic freedom and consequent increase in the standard of living makes no difference to the masses.

The economic development of a country depends on its natural and financial resources, its man power, its scientific advance and the know how of its technical men. But above all it depends on the willingness of the people to work and make sacrifices. There is no substitute for work, or a short cut for development and production to raise the living standard of the people.

Financial Resources

The financial resources of our country are limited. There is not much scope for increased revenue, by increased taxation. As a good portion of the country's revenue is spent on welfare schemes and recurrent expenditure, loans foreign and local seem necessary for development. World Bank loans are given only to schemes approved by it. Aid from foreign countries though they may not have "strings attached" are controlled by other factors. Besides, these loans have ultimately to be paid back with interest. It is therefore desirable to rely mainly on the country's resources and our own efforts to improve the country. There is not much scope for increased revenue by increased taxation. Therefore our industrial and development schemes should not only save foreign exchange but should also produce revenue, to pay back the loan and in addition finance new projects. Otherwise, we will be mortgaging posterity, to tide over our present difficulties leaving no resources to posterity to repay the debts. Our plan of development should therefore be for schemes which will pay and give reasonable return for the capital expenditure. Some of the schemes undertaken by Government are reported to be running at a loss. Though losses may be expected, at the initial stages of an enterprise, before undertaking a scheme we must make sure that it is financially sound. In our schemes, not only savings in foreign exchange but also the net return for the expenditure should be considered. Projects that will require Government subsidy to maintain them should be avoided and undertaken only when they are considered essential welfare schemes. Irrigation and agricultural development appear to come under this category at present. The more land you develop and cultivate the more has Government to pay as subsidy to the cultivator under the guaranteed price schemes. While in most countries irrigation schemes have paid handsome dividends on the capital expenditure, in Ceylon the revenue collected as irrigation rates, is not adequate even to pay the maintenance costs. Frequently even these low rates get waived. With scientific and improved methods of cultivation paddy yields have shown a marked increase in recent years. There is therefore a justification for a more realistic levy of water rates.

Man Power

Man power is one of the natural resources we have in abundance which can increase production if correctly employed. But on the other hand due to a lack of a comprehensive plan to make the best use of the available resources, man power which should be an asset has become a burden of ever increasing unemployment.

There are labour intensive schemes where progress has been slow for want of labour; and there are other schemes for which expensive machinery is imported when the work can be done by manual labour. This is a heavy drain on our external assets.

A manual labourer is still considered inferior in status, to a white collared worker, and people are ready to change over from manual work to a clerical job, even though the wages earned in the latter may be less. What is requires is a reappraisal of values and a social transformation which will produce men and women who will realise the dignity of labour and are eager and willing to work and make sacrifices for the development of the country. Legislation without a corresponding change of heart of the people will not be of much avail. Government has made legislation to improve the condition of the workman but the latter has taken this for granted and as a bribe to get his vote. He has not reciprocated by realising his obligations and carrying them out. It is unfortunate that our Trade Union leaders are only concerned with fighting for the rights and privileges of the workers and increased pay for them which will in turn benefit them personally and keep them in power. There has been no exhortation by them to the workers to realise their responsibilities and at least work for the wages and privileges they enjoy. Workers cannot conscientiously ask for increase in wages if they do not contribute to increased production. If unfortunately democracy is understood to mean rule by the majority for the benefit of the majority, then the Politicians will be tempted to have their eye on the vote and not on the real welfare of the country and its people as a whole.

Incentive to Labour

However elaborate your plans may be development will not turn out to be economical, unless everybody concerned co-operates to make it a success. If a workman is paid according to his attendance, and not according to his output, economic development will be impossible. Either the management should be empowered to sack the slackers, or payment should be made dependent on the output. Incentive for work, is either patriotism and love of the country or pecuniary gain or fear of dismissal. Unfortunately, in this country patriotism is equated to narrow nationalism or even to communalism. The hire and fire basis seems to have worked satisfactorily in the past to keep down costs but now it is almost impossible to punish a worker for slacking or indiscipline. A "labourer is worthy of his hire" means not only that a labourer should get adequate pay for his work, but also that his work should be adequate for the pay he receives.

In basing pay on output experience and great care are necessary to determine the norms for a workman. In some Government Departments where task work is adopted, you find the task completed in four hours whereas on a daily attendance wages scheme the task will not be completed even in eight hours.

You may plan a work in all detail, but to execute the work economically the co-operation and enthusiasm of all concerned in carrying out the plan is necessary. The plan should therefore be a National Plan for the country as a whole which can be enthusiastically supported by all sections of the people. It is therefore necessary that the Plans should be made public and freely discussed by the people. It will then become the People's Plan.

SECTION A—MEDICAL & VETERINARY SCIENCES

Presidential Address

(21st November, 1963)

INDIFFERENCE TO BASIC PRINCIPLES AND ITS CONSEQUENCES—A CLINICAL SURVEY

by

CHANDRA P. DE FONSEKA

Before I discuss my subject this evening I wish to thank the members of Section A for having honoured me by electing me your President for the past year. I have found this year very stimulating and had the opportunity of making many new friends. I specially value this because, in spite of Ceylon being a small country, many of us who are in the scientific professions do not have sufficient occasion to meet each other except perhaps on social grounds. This unfortunately seems very marked among the medical fraternity. My special thanks are due to the Honorary Secretary, Dr. Malcolm Fernando, for his magnificent organisation, with statistical precision, and also my apologies to him for having suddenly decamped to Peradeniya just before these Annual Sessions. This left him with a lot to do on his own and the antediluvian system of University communications where a letter takes about five days to reach me there, did not, I am sure, help him.

The subject I have chosen is unusual. It may seem rather impertinent of me to talk about basic principles to an audience such as this, but I make no apology; our work requires that we keep them uppermost in our minds and I am sure that indifference to them, which is common but unrealised is a fertile source of confused thought. This is detrimental to scientific advancement and very serious in medical practice.

This subject came to mind as a result of the deliberations of a Committee of the Faculty of Medicine which is reviewing the medical curriculum and my own subsequent observations. It was stressed repeatedly in this Committee that basic principles should form the foundation of instruction throughout the course. I therefore asked myself—"What really are basic principles?". They may be defined as generalisations based on fundamental facts. Such principles are of very great value not only in science and medicine but also in any other field of study. They help logical thought, makes cramming unnecessary and helps to solve unexpected practical problems.

However many generalisations have exceptions—the more the exceptions the less satisfactory the generalisation. Therefore to be most helpful a basic principle should have no exception, in fact, it is only then that we can call it well and truly *basic.* I stated earlier that basic principles are based on fundamental facts. Therefore we should note that a basic principle which guides a clinician frequently depends on facts learnt in the preclinical years and a basic principle in pathology often depends on an anatomical or physiological fact. This however is not always so, for example the principle that a history and a clinical examination must precede radiological investigation is based on the fundamental clinical fact that, otherwise, one is very liable to error. On the other hand the basic anatomical fact that arteries become smaller towards the periphery of the body forms the basic principle of the pathologist who thinks of arterial embolism. These are very simple examples but no matter what he is teaching, it behoves the medical teacher to lay the emphasis on basic principles because the student is unable to do this for himself.

I would now like to illustrate, with a slightly more complex problem how we may arrive at a basic principle. Take for instance the control of growth of living tissues, not only those processes involved in progress from conception to maturity, but also all instances where cells in the body have normally to divide, multiply and differentiate. Growth consists of protoplasm producing more protoplasm by complicated biochemical processes leading to cell division. We know that all this depends on certain factors such as the availability of raw material, the correct environment and the efficient disposal of waste products. Given all this growth will proceed. This has been successfully achieved in tissue cultures. The experimental scientist can influence this growth in many ways, for instance by lowering the temperature growth will be retarded. On the other hand he might even accelerate it. A good experiment illustrating acceleration is that when tadpoles are fed with thyroxine they change into frogs in a few days. These frogs are however far from normal, they are small, weak and die soon. No one has yet succeeded in hastening the development of a normal frog from a tadpole. Myocardial tissue from a chick can be kept alive and will grow and exhibit contractility for many months in tissue culture. But no matter how long it is allowed to grow it will never organise itself into a normal chicken heart. No one has yet accelerated the growth of a chicken so that the incubation period of an egg is reduced. We can ensure that a child will have good teeth but we cannot make them appear early; we can ensure that a wound heals well but we cannot accelerate healing; we can ensure that healing is not delayed just as much as we can ensure that healing of a fracture is not delayed. No one has yet accelerated the healing of a fracture. In other words growth in the *normal and intact* organism depends on the collective effect of a large number of exogenous and endogenous influences, some known but many more unknown, at present, which determine not only cell proliferation but arrangement, differentiation, shape and size. We are therefore helpless so far as normal cell proliferation is concerned and we realise that we are incapable of accelerating the normal growth of even a single epithelial cell. To this there is no exception—it is a basic principle.

At this point in the discussion it is necessary to draw your attention to a source of common confusion in this connection. There are many factors known that may *interfere* with normal growth in the intact organism such as infection of a wound, hypovitaminosis, an inadequate blood supply, anoxia or the presence of a foreign body. It is a well recognised basic principle of therapeutic procedures that any of these factors, if present, should be removed or corrected. It would however be a confusion of thought if, in doing this we believed that we were actively stimulating growth. But such confusion in the minds of trained doctors *does* commonly lead them to believe that preparations do possess that virtue. A common example is the various antibiotic impregnated dressings that flood the market supported by the claim that they stimulate granulation and epithelialisation. They do help, not by stimulating healing but by acting as a shield against continued infection from outside. We can obtain the same protection and the same results with less expense by using a well applied plain or normal saline dressing.

You will now realise that a basic principle states a very simple fact but its explanation and understanding requires some effort. Once mastered and understood however its application is simple. Understanding basic principles is not simple work, but basic principles when understood simplify work.

The application of basic principles results in rational thought; conversely, thought will be irrational if we are indifferent to them. Let us consider the application of the above principle with a simple hypothetical example. If the Health Ministry decides to distribute, free, through our hospitals, a cure for idiopathic baldness would you as scientific medical men agree it was rational, bearing in mind that hair is a product of normal growth of cells? I would not because the claim violates an established basic principle. If it was correct the inventor would have unlocked a door that could change the pattern of our life entirely. He would have found the means of stimulating normal growth in the intact organism which would be akin to shortening the incubation period of a chick, shortening pregnancy, making fractures heal quicker, making granulation tissue grow faster and doing other such wondrous things.

This brings us to the question "Are basic principles themselves always inviolate?" Not by any means. Classic examples of the shattering of then accepted basic principles were witnessed when in 1896 Becqueral demonstrated spontaneous disintegration of atoms and when in 1919 Lord Rutherford succeeded in artificially breaking up atomic nuclei. You have seen for yourself the consequences of those discoveries. Such occurrences are events in a lifetime. When announced they are thoroughly tested and checked, a process that may take a decade or more, and only then are their practical uses worked out. By then their existence is widely known through reliable scientific literature and even through popular magazines. I think it can be safely assumed that in this modern world it would be almost an impossibility for a discovery so fundamental as to shatter one of our well recognised basic principles to be brought to the notice of us scientists through Parliament and a hair restorer or an advertisement. It would be similar to a salesman coming to your door and offering for sale a car that uses water as the fuel for its internal combustion engine.

After this rather protracted theoretical discussion with hypothetical examples I now wish to relate a personal experience to show what happens in reality when there is indifference to this basic principle. Not very long ago a very experienced dental surgeon came before the Ceylon Hospitals' Formulary Committee, of which I was a member, to plead for the inclusion in the Formulary of a course of injections which consisted of an extract of proliferating osteoid tissue. The manufacturers claimed that these injections stimulated the growth of bone on the alveolus where it had been destroyed by chronic paraodontal infection leading to loosening of the teeth. He was sure they were beneficial as he had tried it on many patients with success. On questioning he admitted that in addition to the injections the standard, well recognised treatment to the teeth and gums such as scaling and elimination of pockets of pus was also done. He was unable to say why he did not attribute the improvement to these measures but continued to emphasise the manufacturers' claim. It had not occurred to him that if they stimulated the growth of bone they would have been ideal for treating fractures in any part of the body. If we believe that we can stimulate bone growth by any preparation then we are no different to the ayurvedic practitioner who believes he can do the same thing by an application of herbs and oils. The same basic principle is violated in both instances.

I have so far discussed indifference to basic principles in a very broad way and indicated how it can lead to doctors accepting statements which as scientists they should not. It may affect the advice they give their patients but no grievous harm results. A course of those injections would almost certainly do no harm. It is however entirely a different matter in my own field, clinical surgery. Indifference however is something which I think can be a habit and one who ignores them when he has to assess the veracity of a statement presented to him is unlikely to evoke basic principles to solve a clinical problem. Therefore his clinical work is likely to be characterised by irrational thought with detrimental results to his patients. The harm that may be done is exemplified in surgery. I propose to illustrate this by a few cases that have come my way in the past several years. I will explain the basic principle involved in each instance and you will see that they are really very simple.

It is an established principle of the treatment of fresh wounds that surgery aims at removing contaminating dirt and foreign material which carry bacteria, excising crushed non-viable tissue and careful closure of the wound. Antibiotics are of value only after these have been observed, and the introduction of bone grafts into such a wound reintroduces non-viable material. The first case is that of a young police officer who received a wound over his ankle in a motor cycle accident and came under my care 3 weeks later. He had received a compound fracture and the surgeon who dealt with the wound had boiled the bone fragments picked up on the road by the police, inserted them into the wound and stitched it up. The violent resulting infection destroyed a large area of skin and you could see the fragments of bone in the wound. Basic principles were applied in the management — the fragments were removed, the ankle was immobilised and elevated and the wound protected from further external infection with saline dressings. The inflammation rapidly subsided and healthy granulations appeared. The skin defect could only be restored by bringing a square of healthy skin from the thigh on the same side using the opposite foot as the carrier. He was eight months in hospital and is now back at his job. The violation of basic principles resulted in the wide skin destruction necessitating multiple-stage grafting and prolonged hospitalisation.

My next case demonstrates very much more serious consequences in a similar case. A young man who was assaulted received two small wounds in the leg and fractures of both bones. He was promptly taken to the theatre, the wounds cleaned and the leg enclosed in plaster. Forty-eight hours later he was delerious and profoundly shocked. I saw him then and a diagnosis of fat embolism was suggested. Basic principles demanded that the plaster be removed and this revealed massive gangrene extending to the thigh. An emergency amputation was done but he died a couple of days later, still shocked, from a fulminating staphylococcal pyaemia. In the amputated leg there was grass and soil buried within the wounds.

This is the picture of massive gangrene of the forearm of a young boy who had received a simple fracture of the radius and ulna a few days previously. The gangrene resulted from firm bandaging by an ayurvedic practitioner. These two cases of gangrene following incorrect treatment of two fractures demonstrate that basic principles are so basic that their violation by the most highly qualified or by the completely untrained leads to identical results.

The commonest reason for a surgeon to open the abdomen is to remove the appendix. But any pathologist will testify that far more normal than abnormal appendices are removed. Surgeons cannot be blamed for this because it is an established principle that if there is any possibility that appendicitis is the cause of tenderness in the right illiac fossa, the appendix must come out. However if the appendix is normal, not to investigate further is a violation of a basic principle. To this again there is no exception and I do not mean elaborate barium examinations but simple microscopy of the urine. This picture was taken immediately after the removal of an impacted stone from the penile urethra. You can see the recent scar of an appendicectomy in the right illiac fossa. The appendicectomy was done a week previously and he was discharged. Two days later he was readmitted with acute retention of urine. The stone during its passage down the ureter had caused pain simulating appendicitis. It is my belief that right renal colic is the commonest cause that simulates appendicitis.

Severe shock is one of the most serious conditions a surgeon may be called upon to treat. It is a basic principle in such cases that the cause be determined and rectified if recovery is to occur. My next case illustrates indifference to this simple rule. A middle aged fit woman underwent an abdomino-perineal resection of the rectum for an early carcinoma. She developed a moderate degree of shock at the end of the operation but recovered with blood transfusion. She was getting on satisfactorily when on the fifth day she suddenly went into profound shock. In post-operative shock due to trauma or blood loss, once the patient recovers from it with transfusion and the end of the operation, shock does not reappear in the absence of further bleeding, pain or a complication. This patient had no demonstrable complication, no pain and no bleeding; the wound and colostomy were satisfactory, there was no peritonitis and the lungs were clear. There was nothing to point to an embolus. A diagnosis of coronary thrombosis was confidently made. For forty eight hours she was treated with pressor drugs, I.V. fluids and small doses of cortisone. Shock persisted but she was still alive and therefore an electrocardiogram was done. This revealed a normal tracing. I think that in circumstances such as this a cardigram was obligatory in the first instance to check on the clinical diagnosis in keeping with the basic principle that the cause must be ascertained with certainty. After the normal tracing was seen the only condition left was acute adrenal failure and as this was not considered earlier because there was no cardiogram. Consequently she did not have sufficiently large doses of cortisone for such a case. The small doses given empirically probably helped her to stay alive. By the time full doses were given it was too late and she died. An interview with the relatives soon after the normal cardiogram was seen revealed that she had been having small doses of steroids for the past two years for occasional joint pains. Of course I will admit this was an unusual case but I do wish to emphasise that it is exactly in this type of case that discipline to basic principles is most rewarding.

Here is another example of an unusual case, or more correctly a familiar symptom with unusual features: swelling of the parotid region in a young man and a distended external jugular vein. A diagnosis of thrombosis of the vein was made, a justifiable but unusual one. Short wave diathermy was prescribed and continued for *three months* while the swelling progressively enlarged. It is an elementary basic principle that no treatment given to any lump, *no matter where*, should be continued in the absence of a favourable response without taking further measures to establish the diagnosis. These further measures often involve a biopsy. I would say that two weeks is the maximum permissable time. Biopsy in this case eventually revealed a carcinoma of the parotid, by then far advanced. Indifference to the principle resulted in loss of valuable time.

My last example illustrates the value of careful examination of pus. A healthy woman presented with a submandibular abscess of one week's duration. There was no demonstrable sepsis in the mouth. The salivary gland and duct were normal. But the swelling appeared to originate from deep tissues. Tuberculosis seemed unlikely with the short history. Owing to these conflicting findings we decided to incise it and examine the pus carefully and it was only because we did this that the diagnosis was established. Floating in the ounce or so of thick pus we found a grain of rice complete with husk. I believe that the sharp stalk had pierced the mucosa and the seed had worked its way into the tissues due to the movements and caused the abscess. Examination of pus does not only mean sending it for elaborate laboratory tests—it starts with macroscopic inspection. It would have been the easiest thing to allow this piece of vital evidence to vanish with the pus into a sucker, and labelled this another plain abscess.

Medicine is rapidly changing today unlike three or four decades ago. Whereas then the therapeutic materials about which the student received instruction remained unaltered throughout his professional career, today's drugs and methods in use this year are superseded by new ones in the next. Therefore the young doctor has to make his own assessment of these newer remedies without a teacher to guide him. This is one of the reasons for the modern trend towards refresher courses, but the vast majority cannot attend them. They have therefore to rely on information they

receive and the commonest source of such information today is the drug advertisement. It is natural to expect these to extol the virtues of the product. To illustrate this tendency which seems world-wide, the Medical Letter on Drugs and Therapeutics, published in New York, in its issue of July 5th 1963, draws attention to a recent advertisement of the tranquiliser 'Librium' by Roche. This bore the picture of a small boy and a distraught mother. The caption read—"When anxiety and tension create major discord in parent-child relationships . . . . " and there was a panel of 188 references to the literature. The Editorial Board of the Medical Letter studied these references—11 could not be traced. Of the remaining 177 only 3 or 4 had anything to do with child-parent relationships and even these were without controls. In another ten or so the children referred to were adults whose parents were still living! The Editors point out that this sort of misrepresentation is very prevalent in drug advertisements generally. I think that it shows that doctors are considered gullible. As no doctors can spend hours in a Library checking the veracity of references to assess the value of various claims it is my belief that only rational thinking, based on basic principles, will help sift fact from fiction. That is why I feel that instruction, not only based *on* such principles, but also instruction in *what* they really are and *why* they are important is equally necessary. This duty rests on the medical teachers, especially so on the clinical teachers. But no teacher can do this unless he himself adopts the same fundamental approach and makes it his second nature. In such a practical science as medicine, where students learn by observation, the responsibilities of teachers to discipline themselves is obvious. This should not be difficult as the application of basic pinciples requires no complicated equipment.

SECTION B—AGRICULTURE AND FORESTRY

Presidential Address
(20th November, 1963)

THE EXPANDING FRONTIERS OF SOIL SCIENCE

by

F. S. C. P. Kalpage

Early ideas about soil

From the beginning of civilization mankind has been interested in soils but the knowledge acquired was purely empirical. The scientific study of the soil began in the 19th century when the newly flourishing science of chemistry was applied to investigate plant growth. Plants were shown to consist of a number of different elements, many of which came exclusively from the soil. Among the scientists whose efforts contributed towards an understanding of the nature of the elements supplied by a soil were de Saussure and Boussingault in France, Liebig in Germany and Lawes and Gilbert in Britain. These early workers considered the soil as a storehouse of plant nutrients. Growing crops absorbed these nutrients from the soil and the addition of fertilizers was necessary to make good this loss. The idea that the soil was a simple storehouse of plant food continued to exist until about the second half of the last century.

Modern pedological studies

The study of the soil as a distinct phenomenon, a natural body with definite physical, chemical and morphological characteristics commenced with the investigations of V.V. Dokuchaev and his school of workers in Russia. Dokuchaev's work was brought to the notice of other Western workers by Glinka through his German edition of "The Great Soil Groups in the World and their Development" while Glinka's book was translated into English by C.F. Marbut of the U.S.D.A.

Dokuchaev was impressed by the appearance of a vertical cross-section of a soil which could be divided into a number of different layers or horizons each of which had distinct physical, chemical and morphological properties. Such a vertical cross-section, called a *soil profile* (Fig. 1) has imprinted on it the history of that particular soil. The soil profile came to be recognised as the unit of study in pedology, the science which deals with the genesis, classification and distribution of the different soil types.

The soil-forming factors

The modern approach to the study of soil as enunciated by Dokuchaev has been useful in understanding the factors responsible for soil genesis. Parent rock, disintegrating under the combined influence of weathering agents, is transformed physically and chemically into the parent material on which the other soil forming factors operate (Table 1). *Climate* and *biosphere* acting on the *parent material* situated in a given *topography* in the course of *time* give rise to soil. The possible variation in these soil forming factors is virtually unlimited and their combined effect can thus lead to an infinite variety of soil types.

Soil survey and classification

Pedological studies began in the vast stretches of land in the U.S.S.R. and in the U.S.A. and are now carried out in every part of the world. Soils are surveyed, mapped out and classified. The use to which such surveys are put usually determines the scope and extent of the survey. The use of aerial photographs have assisted greatly in the mapping of soils, although in tropical forest regions a heavy forest cover detracts from their usefulness to some extent.

Few countries today will embark on agricultural development programmes without an adequate soil survey. In Ceylon the pioneer investigations of Joachim and his associates resulted in a provisional classification of Ceylon soils (Fig. 2) which was first presented to this Association in the Presidential Address to Section B in 1945.

The progress made since then in the identification and classification of tropical soils has made a reappraisal and revision of Joachim's work necessary. Recently Moorman and Panabokke (1961), using aerial surveys, profile studies and laboratory investigations have suggested a new approach to the identification and description of the more important soil groups of Ceylon (Fig. 3). Besides the creation of a new Great Soil Group in the Reddish Brown Earths of the Dry Zone, other soils of Ceylon have been accommodated within similar Great Soil Groups identified in the U.S.A., Australia and a few South East Asian countries.

Pedology deals with the soil as a complete entity and pedological investigations have advanced the frontiers of soil science considerably. But it is from the point of view of plant growth that soils are of practical use to man. Plants extract water and certain nutrient elements from the soil and use the soil also as a means of support. Soil fertility depends on the ability of a soil to sustain a growing crop and to maintain yields at the highest possible level.

Soil texture and structure

Among the scientific disciplines that have helped to push back the frontiers of soil science are physics, mineralogy, chemistry and biology. The nutrient-supplying power of a soil depends on its physical, mineralogical, chemical and biological properties. Soil texture and structure, soil density and porosity, soil aeration and the water-relationships in a soil have all been intensively studied. No longer are soils referred to merely as being 'light' or 'heavy' according to the ease with which mechanical implements can be used on them; the exact proportions of sand, silt and clay can be specified using methods which are sufficiently accurate and easy to carry out.

Even more important than texture is structure which may be defined as "the arrangement and stability of the different sized soil particles". Here is a field in which, in spite of numerous investigations, progress has been slow. With the exception, perhaps, of submerged rice soils, structure determines root aeration and water movement. Density, real and bulk, are useful in evaluating pore space but the relative numbers of micro- and macro-pores are more important than the total porosity.

The stability of soil aggregates under cultivation, and particularly under the impact of beating rain drops, is a property of much practical significance under tropical conditions. The liability to erode under the impact of tropical rains will depend on the extent of this stability. The formation of surface crusts which retard infiltration and will consequently increase surface run-off and hence erosion poses a problem to which the only hitherto practical approach seems to be the use of a stubble mulch.

Many tropical red clays have an excellent structure due to stable micro-aggregates formed between iron oxide and kaolinite. Sumner (1961) has reported that plates of kaolinite are joined by iron oxide in an irregular arrangement, the positive spots developed on the iron oxide being held against permanently charged negative spots on the kaolinite crystal. As the pH is raised, the number of positive spots on the iron oxide decreases and this probably accounts for the bad effect of lime on the structure of these soils.

Soil water

A good soil structure will promote aeration and facilitate the movement of water in soils. The amount of water stored by a soil depends on a number of factors besides structure; notably the clay and organic matter contents. The water considered to be available to plants will be stored at suction pressures between pF 4.2 (wilting point) and about 2.7 (field capacity). A number of techniques are now available for measuring this water in the field; tensiometers, gypsum,-fibre glass - and nylon-blocks, and neutron-scattering methods are used. Irrigation and drainage need no longer be carried out in a haphazard manner and water conservation and effective water use become more exact practices.

Theoretical considerations of water movement in soils have been investigated and the old capillary tube hypothesis replaced by the concept of water films of varying curvature filling and emptying the soil micro-pores. Root elongation and water movement are both instrumental in the provision of water to plant roots. An important function of a soil is to provide water for plant growth. This particular aspect of soil science has received, and continues to receive, the attention that it certainly deserves.

Soil clay fraction

Most of the chemical activity of a soil resides in the soil colloidal material, both the clay and the humus. The clay fractions of soils have been much studied by X-ray diffraction, thermal analysis, electron microscopy, electron diffraction, optical and chemical methods. The crystalline nature of the clay minerals has been elucidated and the properties and behaviour of these minerals under a variety of conditions studied; in particular, the existence of isomorphous substitution of atoms and ions resulting in the excess negative charge, to balance which, positive ions are attracted towards the clay particles. Ion-exchange results in several other properties and largely influences soil reaction.

In Ceylon, Panabokke (1959) reported on the mineralogy of the clay fractions ($<2\mu$) of samples from four profiles in the Dry Zone of Ceylon. Kalpage, Mitchell and Mitchell (1963) have determined the mineralogical composition of the clay, silt and sand fractions from soil profiles representative of four of Ceylon's major soil groups and have shown that the mineral assemblages in these fractions can be correlated with the pedogenesis and the degree of maturity of the profile.

Soil acidity and alkalinity

Each plant can grow only over a certain range of pH but extremes of acidity and alkalinity are both harmful. Acid soils are prevalent in regions of high rainfall and excessive leaching of the basic ions; alkaline soils are found in arid regions where salts tend to accumulate. In Ceylon both types are found; acid soils in the low-country Wet Zone and alkaline soils scattered in a few areas throughout the Dry Zone.

Some crops, like tea, prefer soils that are acidic and tea will thrive on soils with a pH of even about 4; most crops, however, prefer a soil reaction around neutrality (pH 7). Recent investigations on the lateritic rice soils in the Hapitigam Korale in Ceylon have shown striking responses to liming; yields were increased by as much as 20 bushels per acre by applying slaked lime at the rate of 6 tons per acre (Ponnamperuma, 1958).

Nye (1963) has pointed out that at pH 5.0 (in water suspension) a tropical ferruginous kaolinitic soil does not automatically respond to lime as temperate soils will. Below pH 5 responses to lime have been obtained, but above it they are rare. Indeed, Schuffelen and Middleburg (1954) reported that liming decreases the soil permeability of lateritic soils until a pH of 7 is reached after which the permeability rises again with further additions of lime.

The incidence of soil salinity and alkalinity is confined to a relatively few scattered areas in the Dry Zone of Ceylon but saline and alkaline soils are of wide occurrence throughout the World. The work at the Salinity Laboratory in Riverside, California, (Richards, 1954) has helped to characterize saline and alkaline soils and to study remedial measures. Salt content, exchangeable-sodium and pH are used to distinguish between saline, saline alkali, and non-saline alkali soils.

Submerged soils and redox potentials

In several parts of the tropics there are badly drained soils which inhibit plant growth. Rice is grown mainly under flooded conditions and rice soils have properties which are markedly different from upland soils. The study of flooded soils and soils with impeded drainage has been facilitated by the use of the concept of redox potentials.

Pearsall and Mortimer (1939) in their classical researches associated low redox potentials with poor aeration and anaerobic conditions, while well drained aerobic situations were characterized by high redox potentials. The Japanese were quick to realise the importance of these findings in studying the physico-chemical properties of rice soils. The profile differentiation in a flooded rice field revealed the existence of a thin surface oxidative layer overlying a reduced greyish horizon which constituted the main portion of the furrow slice. Oxidative conditions further down can result in the formation of ferric hydroxide and manganese dioxide rich layers as observed by de Gee (1950).

The practical implications of redox petential profiles in rice fields have been used to advantage particularly by the Japanese. They found, for example, that ammonium sulphate gave better results when ploughed into the reduced zone rather than when broadcast. Surface applications of ammonium sulphate resulted in oxidation on the surface and subsequent loss by denitrification when the NO_3 ions leached down through the reduced zone.

Alberda's (1953) finding that just prior to the initiation of inflorescence primordia, the rice plant develops a mat of surface roots capable of rapidly assimilating the NO_3 ion from the surface layer indicates that top-dressing with nitrate may be carried out at this stage of growth. Alberda (1953) showed that the diffusion of oxygen into the soil from the roots of rice plants was reduced during the period of stem elongation. In a field experiment at Peradeniya, Kalpage (1963) has shown that a growing rice crop tends to lower the redox potential of the soil in the root zone thus confirming Alberda's point of view.

A number of physiological diseases of rice are associated with toxic substances produced in the rhizosphere as a result of critically low E_h values. Jeffery (1961) has defined mathematically the conditions under which rice growth is restricted under extremely reducing conditions. In Ceylon, poor rice yields in the ill-drained areas of the low country wet zone may be due to hydrogen sulphide and other toxic substances produced at very low E_h values. The decomposition of the weeds growing on these rice fields may also result in toxic organic acids like butyric acid which impair root development.

Soil organic matter

Soil organic matter consists of plant and animal residues in varying stages of decomposition. The most resistant to further decomposition is the so-called *humus*, a brownish-black relatively inert material. Humus has been invested with magical properties by those who are not too well-informed, and the organic-farming enthusiasts advocate the use of organic materials only for this reason. Scientists have however studied the properties, origin and mode of formation of humus and have found that it has several interesting and valuable properties. Humus contains nutrients, the major elements as well as the trace elements, but its more important properties are its water-holding capacity and nutrient-retaining power.

In tropical soils, temperature and moisture conditions are usually very favourable for the proliferation of the organisms responsible for the breakdown of the added organic material. Organic matter decomposes rapidly and tropical soils, on cultivation, tend to become very low in organic matter content. In natural forests, however, the rapid circulation of the elements between the vegetation and the soil encourages a lush growth and gives the illusion of a fertile soil. Organic matter seems to play little part in the stability of microaggregates in tropical latosols and the level of organic matter may fall very low without deterioration in their structure (Nye, 1963).

The cation-exchange properties of humus are particularly important in kaolinitic tropical soils since humus contributes the larger part of the exchange capacity in the top soil—about 350 m. equiv. per 100 g. carbon.

The soil fauna and micro-organisms

In addition to being composed of mineral matter, water, air and organic matter, most soils support an enormous population of animals and micro-organisms. The soil fauna consists principally of insects such as termites and ants, earthworms, eelworms and slugs. Termites probably play as important a role in tropical soils as earthworms have been shown to do in temperate soils. Parasitic eelworms cause much damage to crops in all parts of the World. Usually there is no remedy for badly infested soil but eelworm diseases can be checked by practising suitable rotations.

The soil micro-organisms include the bacteria, actinomycetes, fungi, algae and protozoa. Improved methods have been developed for estimating the numbers of these micro-organisms present in soils, their nutritional needs have been studied and their role in soil fertility relationships elucidated. The major transformations carried out by the micro-organisms include the reactions centred on carbon, nitrogen, phosphorus, sulphur, iron and manganese all of which have considerable agronomic importance.

Soil problems in tropical regions

Tropical soils are usually poor in plant nutrients which have been leached away. But their physical condition is good when they contain clay minerals, like kaolinite, which promote aggregation and crumb stability. Often the limiting factors for crop growth are water, which although available in abundance in the humid tropics is not easily held in the soil, and plant nutrients.

Water conservation and effective water use are therefore problems of urgent practical importance in tropical countries. Measures which are recommended include shading the soil with a crop cover or mulch to reduce evaporation losses and improve infiltration properties, slowing down the flow of water over the surface by means of mechanical measures such as contour cropping, terracing and strip cropping on the contour, and improving the water-holding capacity of a soil so as to reduce drainage and percolation losses.

Plant nutrients and fertilizer applications

Plant nutrients, which are deficient in the soil or even if present are rendered unavailable to plants, can usually be supplied in the form of fertilizers. Fertilizers are being used in increasing amounts in the newly emerging countries of the tropics and sub-tropics. In Ceylon, in 1952, nearly 100,000 tons of fertilizer were imported. By 1962 this had risen to 275,000 tons. At first the plantations, tea, rubber and coconut were the chief users of fertilizers. Today increasing amounts are being used for rice. Fertilizer response trials have been conducted with all these crops and fertilizer recommendations are now being made more accurately for the particular varieties used and the districts concerned.

Nitrogen

The problem of nutrient availability is one of particular concern to tropical regions. The main source of nitrogen is the organic matter in soils. The soil micro-organisms play an important role in decomposing proteinacous materials into simple ammonium compounds which in turn are converted into nitrites and nitrates. Other organisms fix nitrogen in the soil, aerobically or anaerobically, while still others living symbiotically with leguminous plants fix nitrogen in the material of their bodies and subsequently make this nitrogen available to plants.

Soil pH is an important factor determining the survival and spread of root nodule bacteria like rhizobia introduced into the soil. Acid soil conditions are harmful. Superphosphate and trace elements sown in close contact with inoculated seed are likely to depress nodulation. Partial neutralization of the superphosphate with lime or ammonia and broadcast rather than drilled applications of the trace elements will prevent these adverse effects.

The importance of molybdenum in nitrogen fixation by nodule bacteria has been demonstrated in the field, and one of the beneficial effects of liming is to increase the availability of molybdenum present in the soil. Sulphur also appears to affect symbiotic nitrogen fixation chiefly through its effect on nitrogen metabolism within the plant (Vincent, 1962).

These several aspects of the nitrogen cycle in soils are being investigated in many tropical regions and will contribute much to solving the problem of adequate nitrogen fertilization.

Phosphorus

Phosphorus is a major plant nutrient, whose especial significance in tropical soils lies in its ready fixation by the oxides of iron and aluminium which are abundant. In arable soils under aerobic conditions phosphorus fixation proves serious, and continuous, often heavy, applications are the only remedy. In flooded rice fields, however, ferrous phosphate, being soluble, is more readily available but the total amount of phosphate present may be very low, and phosphorus fertilizers will once again become necessary.

The total phosphorus in Ceylon soils is extremely variable, ranging from 40 p.p.m. to about 900 p.p.m. (Kalpage, 1958). In fact vast areas of the tropics have these very low amounts of total phosphorus (Nye, 1963) and the spectacular responses to phosphate fertilizers obtained on such soils owe little to the 'high phosphate-fixing power' widely attributed to tropical soils.

Potassium

Potassium is usually not much of a problem since it is abundant in the felspars which are widely distributed in most igneous and metamorphic rocks. But on sandy soils, due to leaching, potassium reserves may be low and potassium fertilization becomes necessary.

Trace elements

Research in Ceylon has hitherto been confined mainly to the macro-elements N.P.K. The trace elements become a limiting factor in crop growth when they are deficient in soils either through being deficient in the parent rocks or leached out by the rains. They may also, even if present in sufficient amounts, be fixed in unavailable forms. In the determination of the minute quantities of the trace elements present in soils, spectrographic methods of analysis such as those developed by R.L. Mitchell at the Macaulay Institute have proved very valuable.

Soil management

The aim of sound agricultural practice is sustained production where increasing yields go hand in hand with proper conservation practices. Soil studies should be carried out with this end in view. Soil management practices are fairly well established in temperate regions: crop rotations, bare and crop fallows, ley farming, using grass and clover mixtures, mixed farming: all these have been fairly well established. Attempts to translate these practices into the different environment and soils of tropical regions have not always proved successful. The initial fertility of newly-cleared forest areas

is soon lost, yields drop within a short period and the top-soil is washed away by the torrential tropical rains.

Shifting cultivation

While crop rotations are successfully practised in temperate regions, the usual practice of indigenous land use in the tropics is shifting cultivation which involves rotating the land rather than the crops. It is universally admitted that shifting cultivation is an uneconomical use of the land where population pressures are great and agriculturally suitable land is scarce, but several soil scientists have in recent times decried the tendency to condemn shifting cultivation particularly without suggesting more suitable alternatives. Nye and Greenland (1960) have shown that the forest fallow, following two to three years of cultivation, restores soil fertility as nothing else hitherto practised in these regions will. Provided the land is not overcropped and the forest fallow is not unduly shortened, shifting cultivation in tropical forest regions on latesols has been shown to conserve the fertility of the soil. In savanna or tropical grassland, on the other hand, the grass fallow does not restore fertility as much as the forest will and the burning of the grass during the dry season leaves the soil bare and liable to severe erosion as soon as the rains come.

Grassland in the tropics

The role of grassland in improving soil structure and maintaining fertility in temperate countries is well known. Grasses seem to have quite the opposite effect in the tropics. Deep-rooting trees, with roots reaching down to the weathered minerals in the deeply weathered soil material and a canopy which shades and protects the soil, are more useful in maintaining the fertility of tropical soils.

Jane Meiklejohn (1962) has found that the grasssland soils of Ghana are of low fertility and contain small amounts of available nitrogen because of the virtual absence of nitrite oxidizing bacteria in these soils. Nitrogen fixing organisms were generally high in both forest and grassland soils, being slightly higher in grassland. But there were large differences between forest and grassland soils in the numbers of nitrifiers. Forest soils contained many ammonia and nitrite oxidizers while grassland soils contained few ammonia oxidizers and very few or no nitrite oxidizers. The absence of any nitrite oxidizers in the grassland samples taken after the start of the rainy season was particularly striking.

Leaving the soil without adequate cover is a hazard which cannot be risked in the humid tropics. The bare fallow and clean weeding are therefore not suitable cultural practices in these regions. The use of leys is still handicapped by the absence of suitable legumes and grasses for growing in tropical areas. Recent experiments at the Dry Zone Research Station, Maha Illuppallama, have been directed towards this end. Fernando (1961) has shown that swards of *Brachiaria brizantha* with legumes such as, *Alysicarpus vaginalis*, *Pueraria phaseoloides* and *Centrosema pubescens* show promise. Mixed farming which entails the growth of pasture and fodder crops and which will mean more manure for the land must eventually be used in conjunction with suitable crop rotations if shifting cultivation is to be replaced by a more stable form of agriculture.

The soil cannot be considered in isolation except in mere academic and philosophical studies which are a luxury that a country such as Ceylon can ill afford to indulge in. This review of the expanding frontiers of soil science has taken us beyond the study of the soil as a separate, isolated entity into a consideration of soil fertility and proper land use. Soil studies are intimately linked with land use. This fact is being increasingly realised and is a happy augury for the future.

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SECTION C—ENGINEERING

Presidential Address
(21st November, 1963)

"WHEN PLANNING ENGINEERING PROJECTS... ...WITH SPECIAL REFERENCE TO PUBLIC UTILITIES"

by

H. D. S. A. GUNAWARDENE

Belonging to what might be termed a minority community in the Engineering Profession makes it necessary for me to thank the members of the Engineering Section of the C.A.A.S. all the more for the honour they have done in electing me President of the Section for 1963. It will be my endeavour today to draw your attention to an aspect of National Development, which to my mind deserves a loftier place than it now appears to occupy in our country. Much of the substance of this address will permit general application in most Engineering Projects but you will pardon me if, on occasions, I illustrate some of the points by referring to Telecommunication Engineering; I owe it to the particular branch of Engineering that I am now engaged in.

The state of development of the Public Utilities of a nation or country provides an excellent criterion of the general advancement of the country in as much that the Public Utilities represent those types of business on which the public relies for an essential service. Water, Electricity, Transport, Broadcasting, Post and Telecommunication Services are the most important of these Public Utilities, and a serious interruption to any of them would bring in its wake problems which could virtually cripple the life of the community. It is perhaps not out of place to mention here that the current tendency in most countries striving for vigorous development is to bring such activities under more or less direct control by the State, in order that their growth will be determined by national interest rather than maximisation of profits either in the short or the long run. An important feature of the Public Utilities is the necessity for some form of centralisation, the degree depending on

both economic considerations as well as the nature of the service. For example, although it would only be economic considerations that prevent each family in the community from having its own Gas or Electricity Plant, Broadcasting or Postal and Telecommunication Services by their very nature would not admit such a set up. Further, in a field such as telecommunications, centralisation also implies an impossibility of competition at least in a given geographical area—for this would mean that telephone users will have to subscribe to each of the competing systems. Thus Public Utilities imply monopolies whether by the State or by Private Enterprise. In turn these monopolies carry with them certain obligations, the most important of these being the ability to provide a reasonably good service or product at the lowest possible cost. Clearly, whether operated by the State, or by Entrepreneurs, a Public Utility Administration which cannot meet this requirement is failing in its duty, the more so when it is realised that the essential nature of their products in a developing economy almost guarantees a steadily increasing number of users. It might be mentioned here that a reasonably good service implies that the product should be readily available to any customer who requires it. As for lowest possible cost, a Public Utility, like any other undertaking, represents an investment. A return sufficient to attract capital would be expected by a private concern while the general taxpayer would be unwilling to subsidise such a service if it is operated by the State. It is important therefore that the cost of the service or product should be kept at a level to satisfy this requirement while bearing a consistent relationship to other price levels. Proper planning is essential to achieve this object.

In recent times the word Planning has found an almost hallowed position in Economic literature particularly in under-developed or developing countries. In his "Principles of Economic Planning", W. Arthur Lewis gives some 6 different senses in which the term can be used, but viewed generally, Planning can be considered as a process to the confines of a particular field or as a basis to the wider vista of a national economy. It is inevitable that Professional Engineers are more concerned with the former aspect, but it cannot be gainsaid that a basic understanding of National Economic Policy must strengthen the judgment of the planning engineer. In passing, it is worthwhile noticing further that the relationship of Planning to Policy also has a dual nature, in that Planning can be used to formulate new Policy or to apply already accepted Policy to a new programme or project. The former conceives Planning as an advisory function while in the latter planning gives meaning to action by relating such action to goals.

The concept of Planning as an exercise in Operations Research, must also, I feel, be mentioned here. Those who recall the substance of a Presidential Address delivered by Prof. A.W. Mailvaganam some years ago in Section E of our Association will find much food for thought in this respect.

Before proceeding to the details of Engineering Planning, a word about the psychological aspect would not be out of place. Planning, like most, if not all, economic activity is motivated by the fact of human wants. The replacement of the laissez-faire doctrines of early times by ideas of planned action must be considered as but a natural stage in evolution and even those who abhor ideas which might be called regimentative cannot help recognising the achievements of planned action whether on a national or project scale. On a national level, the reconciliation of the ideas of planning with the freedom of the individual appears to be a problem facing democracies but after all correct planning implies the discovery and implementation of the interests of the "common man" and this is a fundament of representative Government.

For the purpose of this address I would like to treat the following as essential stages in the Economic Planning of Engineering Projects:—

I. Collection of Data.
II. Selection of Equipment, Sites, etc.
III. Programming and Progressing.
IV. Engineering and Budgetary Control.

I. Collection of Data

The primary aim of the Project Planner can be put in short as the economic matching of the supply to the demand of the product of the project, not only in the immediate future but over a period of time. This is generally true whatever the project and especially so where Public Utilities are concerned. Here I use the term Public Utilities in its wider sense to embrace not only services such as Electricity or Telecommunications but also Public Sector Projects for the manufacture of essential requirements (whether they be Petroleum Products or Fertilisers).

Hence the planner must know the demand for the product in all its detail on the one hand, and what resources will be available for implementation of the plan on the other. Applied to Public Utilities, the former involves a forecasting process which is generally based on extrapolating the past figures, supplemented by experienced judgment. This corresponds to the process of Market Research as carried out by most large scale manufacturers of consumer goods.

On the other side, the resources would comprise Money, Materials, and Men including Managers. The availability or allocation of money would naturally depend on the priorities and as far as the Public Utilities are concerned, is often a political factor; but here too the amounts and dates need to be known well in advance at least on a budgetary scale.

It is often thought that if money were available materials and men for large scale projects should be readily available. While theoretically true, the fallacy of this idea under practical conditions is only too evident to those intimately connected with Project Planning. Most types of capital goods involved for particular projects are not available "ex stock" as it were, and design time is often a factor to be reckoned with. The trained personnel required for installation, maintenance, and operation, are also only available at "imported" prices in most cases, and full details of their availability at each stage are required for effective programming of the work.

Again, managerial talent is not something that one can easily obtain in underdeveloped territories, and an assessment of its availability is of prime importance; many a project in the Public Sector has invited failure from the initial stages simply because the planners were ignorant of or chose to ignore the resources available in the managerial field.

When the Project requires raw material for its operation, it is worthwhile, at this stage to collect the data relating to this aspect also. Not only the availability but also prevailing prices and transport charges etc. of the operational raw material play, very often, a decisive part in the selection of sites, equipment etc.

II. Selection of Sites, Equipment etc.

The selection of Sites, Equipment etc. is perhaps the most controversial aspect of planning as evidenced by the debates in Parliament whenever a Public Sector project is under discussion. Nevertheless, the role of the Planner is quite clear: whatever the ultimate decisions are likely to be, he has no alternative but to study the economics of the project and advise on the most economical plan which conforms to good engineering practice.

In a study of the economics of a project, it must be realized that various types of buildings, plant and equipment could differ not only in their first or capital cost, but also in their lives and cost of maintenance and/or operation. For this reason the first cost of a project by itself does not give a true indication of "real cost" of the service provided by the project over a period of years.

It may so happen that a project which involves a higher initial outlay than others is by far the most economical in the long run: on the other hand it may be possible to start the project on a small scale and expand it over a period of years in such a manner as to meet the demand as and when it arises. I would like to stress here that all these considerations require a basic technical background if the possibilities are to be weighed economically.

Therefore, for obtaining a true comparison of costs between alternative plans, the engineering economist has to take a long term view over a period of many years, this period being known as the "costing period". Once this is decided, the method of approach is to assess what each alternative would cost annually throughout the period and then calculate in each case the sum of money which, invested now at a standard rate of interest will give a return to off set the annual charges. This sum is called the Present Value of Annual Charges (P.V. of A.C.) and obviously that plan which gives the lowest P.V. of A.C. is the most economical.

I might mention here that viewed in this light, Tender Board procedure which requires the acceptance of the lowest priced machinery has such definite disadvantages that the prudence of its adoption is open to question.

1. Annual Charges

The Annual Charges represent the liabilities that would result from executing the Project and can be classified into three main groups:—

(a) Interest on Capital
(b) Depreciation
(c) Maintenance and Operating Costs.

In the following, I shall deal with each of these factors in detail:

(a) *Interest on Capital:*—The fundamental principle underlying all business transactions or investments is that money can be used to earn more money. This could be done by loaning the money to an institution like a Bank or to an individual or by a direct investment in a business enterprise. In every case the Capital invested should yield a return (assuming of course that the affairs of the borrowing body are managed properly) and conversely, when money is borrowed a liability is incurred in the form of interest, which can be simple or compound; this liability continues as long as the money borrowed is not returned to the lender.

(b) *Depreciation:*—The execution of a project would involve the expending of capital on land, buildings, equipment etc. Except land, all other items such as buildings and plant tend to diminish in usefulness, and therefore in value, as time goes by, the degree depending mainly on the extent to which the item is used. A stage is ultimately reached when the plant can no longer be used either because it is uneconomic to do so, or because it can no longer function satisfactorily; or it may even be that technological advances have made the plant obsolete thereby making even spares unavailable. The time elapsing between the initial installation of the plant and reaching this stage is called the "Service Life", while the value of the plant at the end of its usefulness is known as "Residual Value". The Residual Value will be positive if the plant can be removed and disposed of at a price higher than the cost of removal, or it could be negative conversely. In the case of plant which could be abandoned "in situ" the Residual Value will be zero.

Obviously the difference between the original value (including cost of installation) and the residual value represents a liability incurred by the organisation as a result of the Depreciation of the plant which is an accountable factor in a true assessment of the costs of the project.

In a world of rising prices, it would be inaccurate to state that Depreciation provision serves for eventual replacement of the plant at the end of its service life. Average service life of Public Utility plant could easily exceed 15-20 years and it is common knowledge that, in practice, it would be impossible to purchase identical plant for the original price at the end of that period. On the other hand what the future prices would be in such a length of time is hardly predictable, and in any case there are bound to be technological changes. These factors have certainly led to much controversy in Industrial and Accounting circles, but should not cause grave misgivings as far as choosing between alternate plant is concerned so long as the same basis is maintained throughout the assessments.

There are several methods by which provision can be made for depreciation and I shall deal briefly with each of the most important of these.

(i) *Annual Valuation:*—In this case the value of the plant is assessed every year and the difference between successive valuations is reckoned as the depreciation during the year concerned, the interest earning capacity being ignored.

(ii) *Output Depreciation:*—The depreciation for any year is based on the proportion of the output for the year to the total expected output of the plant during its service life.

(iii) *Proportional Depreciation:*—This method requires the summation of the years in the life of the plant and the contribution for each year is assessed on the basis that it would be proportionately less as the plant ages. For example, if the life of the plant is 10 years the summation would be $1 + 2 + 3 + 10 = 55$ and the first year's depreciation 10/55 of total depreciation. 2nd year's depreciation 9/55 of total depreciation the last year's depreciation being 1/55 of total depreciation.

(iv) *The Straight Line method:*—This is possibly the simplest method in that the annual contributions are assumed to be equal each being equal to $\frac{\text{Expected Depreciation}}{\text{Service Life}}$. Its simplicity and the uniformity of annual contributions is an advantage making it specially useful for decisions on tariffs; the objection is that it ignores the interest earning capacity of money.

(v) *The Sinking Fund method:*—In this method also the annual contributions towards depreciation are equal but it is assumed that these are paid into a fund which bears compound interest at a standard rate, which is usually the same as that applicable to the calculations of present value. The basis is that the Fund, at the end of the service life of the plant, would amount to the expected Depreciation.

Let V be the annual contribution

n be the life of the Plant

and r be the unit rate of interest.

The first payment V will earn compound interest for n – 1 years and will amount at the end of n years to $V(1 + r)\,n - 1$. Similarly the 2nd payment will amount to $V(1 + r)\,n - 2$ while the last payment will be V. The total amount there will be

$$= V + V(1 + r) + V(1 + r)^2 + - - - + V(1 + r)^{n-1}$$

If C = Cost of Plant

and R = Salvage Value, we have

$$(C - R) = V(1 + (1 + r) + - - - - + (1 + r)^{n-1}$$

which when simplified will give

$$V = \text{- - - - - - - - - - - -} \quad \frac{r}{(1 + r)^{n-1}}(C - R)$$

as the annual contribution in terms of decided quantities.

(vi) *Percentage Depreciation:*—In this process the Depreciation for any year is assessed as a percentage of the value of the Plant at the beginning of the year. It is of considerable convenience when the ownership of the plant is liable to change—a factor which is not of much account in Public Utilities.

(vii) *Other Methods:*—Depreciation Provision is sometimes made by allocation of profits as and when practicable or by charging the whole amount as an expense for the year in which the plant is written off. The latter is strictly not a method of provision but accounting and neither scheme is of any use for purposes of cost comparison.

Although we are concerned here with Depreciation Provision for Cost Comparisons, I have taken the liberty of dealing with a number of methods to indicate the variety of approaches possible and also to show that Engineering knowledge ability is required for selecting the appropriate method. Obviously the type of plant in question and the judgment of the engineer are of prime importance in this respect, but he can do worse than consulting an experienced Cost Accountant before making a final decision on what method should be adopted for this cost comparison.

(c) *Maintenance and Operating Costs:*—The Annual charges accruing to a large undertaking on account of maintenance and operation of the plant can comprise of a large number of items. Most of these items have the same nature, so to say, and for purposes of a cost comparison it is not always necessary to compile them separately at this stage. This is just as well because of the practical difficulties that would arise, especially in the case of a new project. In such a case manufacturers of the plant can render valuable help by giving the planning engineers what data they have, which of course may require modification to suit local conditions.

The most practical approach to the compilation of the charges under this heading would be to list all possible liabilities in the form of Direct and Indirect charges such as:—

(i) *Direct Charges:*—Direct, Labour, Fuel and Power, Transport, Stores.

(ii) *Indirect Charges:*—Building maintenance consisting of rates and/or rent, lighting costs. Administrative costs consisting of salaries, sales (including advertising) travelling, research, pension liabilities, welfare and fringe benefits cost etc.

Other overheads such as insurances, licensing, miscellaneous transport etc.

It is evident from the above that if every single factor is to be considered a mass of detail is involved. Because of this reason, where plant is already in operation, large undertakings find it worthwhile to base some of the costs as percentages of capital after making comprehensive studies at regular intervals. Where such data is available it is up to the planning engineer to judge their relevancy to his particular needs and arrive at his annual charges for maintenance and operation. In practice he would find it worthwhile to compromise between accepting supplied data and compiling his own on a synthesising basis.

2. Present Valuation

I have mentioned earlier that in the decision making process of selecting the site, plant, buildings etc. the preponderant economic factor should be the Present Value of Annual Charges rather than the initial Capital Cost. Since then, I have given in some detail the basis of evaluating Annual Charges. The next stage in a cost comparison between two or more alternate schemes is to reduce to a common base the total annual charges, and Present Valuation achieves this by interpreting all liabilities to a figure which, if invested at a standard rate of interest, would meet these liabilities as and when necessary. This procedure is especially important where any alternative scheme envisages Capital investment at various stages.

The simplest case to which the principle of Present Valuation can be applied is one in which a sum of money A is required at the end of, say, N years. If C is the present value of the amount A and r the unit rate of compound interest we have

$$A = C(1 + r)^n$$

so that $$C = A(1 + r)_n$$

From this one can proceed to determine the Present Value of Annual Charges of each alternative. Suppose a scheme considered would result in a total Annual Charge N for a period of N years, the first Annual Charge being liable at the end of the first year, then,

$$\text{The P.V. of the 1st A.C.} = P_1 \text{ (say)} = \frac{N}{1 + r}$$

$$\text{Similarly} \quad P_n = \frac{N}{(1 + r)^n}$$

$$\text{Hence the total P.V.} = P = P_1 + P_2 + P_3 + - - - + P_n$$

$$= N\left[(1 + r)^{-1} + (1 + r)^{-2} + - - - (1 + r)^{-n} \right]$$

$$\text{i.e. } P = \frac{N}{r}\left[1 - \frac{1}{(1 + r)^n} \right] \quad \frac{N}{r}\left[1 - \frac{1}{(1 + r)^n} \right]$$

I shall leave it to the mathematicians to correct me if this is not the right result of the summation.

Where any possible alternative scheme involves a series of Capital Investments the above procedure has to be applied stage by stage: that is, the Annual Charges arising from each investment is first present valued to its date of investment and these present values subsequently present valued to the date of the first capital investment. The sum of such present valuations is evidently the total P.V. of A.C. of the project as a whole.

3. Irreducible Factors

So far we have considered the purely Rupees and Cents implications of deciding between alternative schemes: the procedure outlined above would provide a reasonably reliable guide to ascertaining the economics of each scheme on a comparable basis. In a competitive society this must necessarily be considered as the primary factor to influence the decision makers. However, in developing countries many other factors do arise in the final choices and these cannot simply be valued in terms of money. Examples could be the necessity for industrialising a particular area and thereby giving a filip to its development as a whole, or conversely, the prevention of population migration to an area which is already overburdened. Or, in the selection of plant, the availability of easier negotiated credit from certain manufacturing countries and the existence of international agreements pertaining to trade or aid or the reliability and the guaranteed existence of the manufacturing firms with their ability to provide spares and replacements required for the plant in time to come. There are a host of such factors including the availability of trained personnel and it is not easy to list them completely because of their sometimes subjective nature. It is so much easier to term these factors as political but the fact remains that they exist and influence decision making in Public Projects. In other words, mathematical calculations of financial implications cannot be used as a substitute for wise reasoning and sound judgment; the former should be regarded as a valuable tool in fashioning the latter. For what it is worth, my personal opinion is "let these irreducible factors form a strong tail, but please don't allow it to wag the dog".

III. Programming and Progressing

Once the basic decisions with regard to sites, equipment, etc. have been taken, the next step would be the preparation of a somewhat detailed estimate of the requirements of men, and money for the Project. This is of course necessarily tied up with the programming of the project because of the general interdependency between resources and time. Theoretically at least the time taken for the completion of a project should vary inversely as the resources available. That is the more men and money are available the less would be the time taken. In practice however, there are limitations on both sides and these must be seriously considered in programming and progressing the project.

Programming and progressing is essentially the instrument by which it is possible to organise and control in a broad sense, the execution of the project. Co-ordination of effort and co-operation between groups and individuals has to be achieved by this process and a knowledge of the possible limitations and their degree is of the utmost importance. In addition to this background knowledge the following information is required to prepare a time order for carrying out the work:—

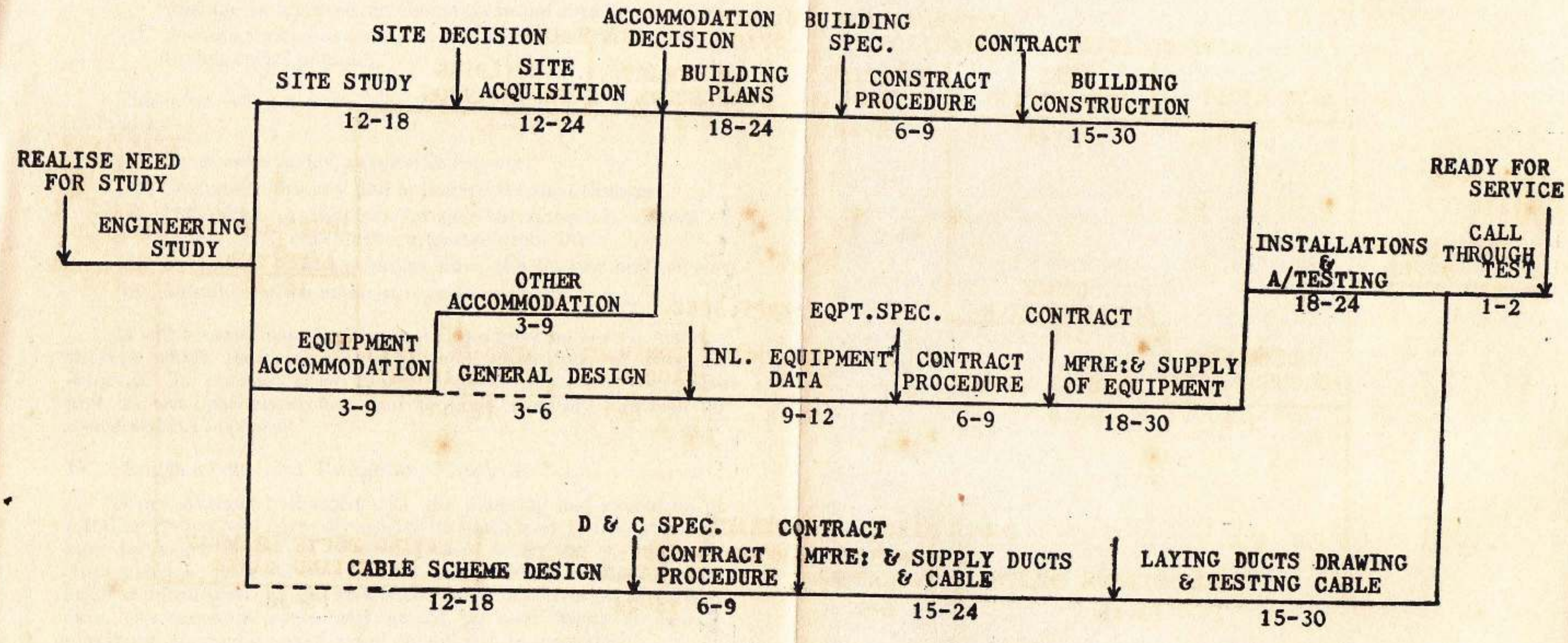
- (*a*) Approximate starting and completion dates.
- (*b*) The units into which the job can be conveniently broken down.
- (*c*) The degrees of priority of items.
- (*d*) The due dates for various commitments.
- (*e*) Estimated delivery periods of materials.
- (*f*) Dates and amounts of available labour of all grades.
- (*g*) Availability of transport and mechanical aids.

Using this information it should be possible to estimate the rates of progress and thereby to knit together the various Units that comprise the project with a view to ensuring that the following requirements are met:—

- (*a*) Starting and completion dates are kept.
- (*b*) Each step is done in the correct sequence.
- (*c*) Efficient use is made of staff.
- (*d*) Priorities within the job are determined and met.
- (*e*) Priorities in relation to other work are determined and met.
- (*f*) The financial commitments are kept to schedule.

As an illustration of the process of programming a large project the chart before shows the planning of a standard telephone system of say 6 to 10 thousand lines. I have given in this case some figures indicating the number of months required for each stage but it must be realized that these will vary from project to project depending on the size of the job, and also local conditions. Moreover, some of the stages may not be required at all in some projects. I would therefore request you to treat this chart as merely typical for a highly technical project.

TYPICAL PLANNING OF A NON-DIRECTOR TELEPHONE SYSTEM



Although I have grouped programming with progressing the latter is really a follow up process to ensuring that the work goes on in accordance with the programme. I shall therefore merely give the why and the wherefore of the latter without going into detail.

Progressing is necessary for:

(*a*) Ensuring that each stage of the work progresses smoothly.
(*b*) Ensuring that there is minimum delay in bringing into use sections which are completed.
(*c*) Showing any need for a change in the programme or in the method of execution.
(*d*) Anticipating difficulties and dealing with them before wastage is incurred or the programme upset.
(*e*) Avoiding inconveniences to those engaged on the job or to the general public.

The information required for this process can be summarized as follows:—

(*a*) Changes in policy on specific aspects.
(*b*) Changes in priority and authority for such changes.
(*c*) Difficulties or problems arising in connected sources of supply, e.g. equipment manufacturers etc.
(*d*) Deviations from the programme, the reasons and effects.
(*e*) Actual progress made at regular intervals.

It will be seen from the above that progressing is a continuous process which requires evaluation and discussions at frequent intervals. In practice these requirements must be met by visits and on the spot inspections and progress meetings between all concerned in the project.

IV. Engineering and Budgetary Control

Every Authority charged with the planning and execution of a Public Project will normally receive its funds from the Government year by year. There are of course cases when the Authority is empowered to raise its own capital as and when required by the issue of debentures etc. but this is an exceptional practice. In either case, the amounts authorized should be used wisely to ensure maximum economic benefits and should not be exceeded.

However, well planned a Project may be, it is possible for the finances to get out of hand unless great care is exercised in control of the expenditure. This control has normally to be effected by means of estimates prepared for the project—in general, annually.

One of the main causes of failures in Public Projects is the absence of well planned annual estimates which can only be prepared by close scrutiny of the work to be done. "Guesstimating" should only be resorted to as a last measure.

Methods of Control fall into two classes, Engineering and Financial.

Engineering Control

Supervising Officers of all levels must exercise a certain measure of control during the execution of their duties to ensure a reasonable performance of work in terms of quality and quantity. The U.M.C. and U.C.C. Systems cannot possibly replace efficient supervision but they do indicate trends and if used intelligently can be useful as a means of control. Each aspect of the work should be progressed to ensure that both men and materials used at every stage should compare favourably with those detailed in the authorized estimates. If departures are observed the reasons have to be carefully examined and remedies effected to bring the situation back to normal before the whole project gets out of gear. If the variations are sufficiently serious it is a clear indication of an unrealistic programme which may require modification.

Financial Control

More commonly known as Budgetary Control, Financial Control is exercised by 2 main instruments, Accounting and Reviewing.

The Accounting and Reviewing process consists essentially of making regular comparisons of actual and estimated expenditure figures, the former being obtained from suitably formulated cost statements. Such statements which must be available regularly—say monthly—should include in an easily discernible form the following details for each class of work:—

(i) Budget allotment.
(ii) Heel taps (i.e. carry over figures).
(iii) Commitments.
(iv) Expenditure for the particular month.
(v) Accumulated expenditure to date.
(vi) Indirect charges.

By this means the financial position at the end of every month is indicated. As the work progresses the results obtained through the accounting machinery have to be reviewed and appropriate action taken when necessary. In order to enable the administration to watch how closely Expenditure and Allotment keep in step, it is a useful practice to review the position with 2 forecasts for the balance of the year. The forecasts can be conveniently done say, 6 months and 3 months before the end of the Financial Year. The former will give an opportunity of adjustment of the progress of the work while the latter is especially useful in case supplementary allotments become necessary for reasons which are unavoidable such as wage increases.

I would like to conclude this brief outline of the processes of Engineering and Financial Control by saying that these controls can be made effective only by close co-operation between the Engineers, Accountants and Administrators.

Miscellaneous Aspects

I have so far attempted to give you the main method of approach by which an Engineering Project can be successfully planned. Now I would like to share some thoughts with you on miscellaneous aspects which arise during the process of such planning.

(*a*) *Basic Organization*:—It is inevitable that the form of the Basic Organization will have some effect on the efficiency of Planning. Assuming that Public Projects must be subject to State Control, this Control can be effected by several methods such as through a Government Department, or a 100% State Corporation or a 51/49% State/Public Corporation and so on. Each type of these Basic Organizations has its own advantages and disadvantages and it is a problem confronting National Policy makers to decide as to what type of organization should be charged with a particular Project.

(*b*) *Human Problems*:—Some of the administrative problems that arise in Planning could be regarded a set of man power requirements to be included in the plan itself. It is, however, difficult to achieve the primary objectives of planning namely, making the best use of men, materials and money by separating them into watertight compartments in charge of Administrators, Engineers and Accountants respectively; the planning body has to consist of men capable of making a co-ordinated effort, while retaining the roles of experts in their own spheres. They should be able to minimise subjective judgment and maximise objective judgment for the general good. One of the essential requirements for this would seem to be an ability to understand and appreciate each others point of view—for which of course some fundamental knowledgeability of each others work is so desirable. To my mind the greatest drawback in this respect is the far too much emphasis placed on the lack of sympathy between administrators, scientists and accountants, particularly when the "scientists" are professional engineers. I venture to say that an examination of the hierarchies of most world-wide large organizations would disprove the oft repeated theory that a good engineer or accountant makes a bad administrator.

(c) *Establishments:*—In a discussion on the Place of Planning in Society published by the Puerto Rico Planning Board as a Technical Paper it was once said that "ordinarily executives are natural enemies of Planners". Sometimes Plans which are economically sound can involve redundancy of staff, extra loading of work, and other effects which tend to deprive some people of what they consider to be legitimately theirs. In an age when organized Trade Unionism has become established it would be very unwise to attempt to force down new ideas on them; an Economic Plan which has the blessings of Trade Unions is a goal to be much sought after.

(d) *The Committee Form*—Although much criticism is levelled against "Committees" by exponents of Administrative Organisations, it must be admitted that a planning authority is compelled to use this form of organization at some level or another—in fact at many. When the problems are complex and the results of their solutions have far reaching consequencies, the advantage of bringing together in mutual discussion several different attitudes of mind cannot be overstressed. At least, it could be regarded as a process of educating the planners themselves.

(e) *Treasury Control:*—"Governmental Organisation, Public Accounting and Auditing practices and Civil Service procedures are not well adapted to the effective management of economic enterprises. A successful adaptation constitutes an important and difficult problem confronting development and planning" wrote Edward S. Mason in Economic Planning in Underdeveloped Areas: Government and Business.

In particular, the problem of Treasury Control indeed assumes imponderable proportions in countries which though self-governing now, have inherited a Colonial System of administration with the Gladstonian concept of "the saving of candle-ends" as the measure of a good Secretary to the Treasury. It is, of course, essential for the planners in the Public Sector to realise their accountability to the State, but they do need the widest possible measure of freedom—within Governmental Policy—if they are to carry out their functions without fear of frustration. The role of the Treasury here must be more to ensure that the money is spent wisely rather than to see that no money is spent at all. The task of convincing the powers that be of the correctness of such an attitude is not always easy, especially with an inherited administrative system, not completely geared to development.

(f) *Buildings:*—Buildings constitute an important aspect of planning any project for the simple reason that practically everything requires a building. Plant which has to idle even for a short period for lack of a building represents money not only lost in storage charges etc. but also idling without producing more. Various types of projects require various types of buildings and economies can invariably be effected by a full consideration of the implications and by planning them in such a manner as to limit them to the barest minimum requirements while at the same time leaving room for extensions to be added as and when required. Experience shows that both ineffective space as well as unitary costs can be reduced with sufficient care in planning.

(g) *Stores:*—A substantial proportion of the money spent on Public Projects in underdeveloped countries consists of costs of equipment and raw material which have to be imported from advanced countries. This not only leaves the planners the problem of deciding which capital equipment to use but a sound organization is also necessary for the purchase, shipment and storage of the thousands of items used once the project gets under way. The principles underlying the purchase and stocking of materials in large efficient industrial organizations should therefore be accepted and follows.

Conclusion

Gentlemen, today our country is passing through a difficult phase in the evolution of economic development. We are stepping out from what was a purely agricultural economy into one which is more diversified. Industrial activity is going on at a pace which is slow by absolute standards but which is definitely faster than has been ever before in this country. Large scale projects in the Public Sector are taking shape but unfortunately not all of them are turning out to be economic ventures. It behoves thought why this should be so. Most projects must necessarily involve some branch of engineering and I submit that engineering on this scale cannot be independent of economics. I have striven in this address to indicate to you the factors that must be taken to account in planning engineering projects which would also be economically successful. I hope in this process that I have not encroached too much into fields which economists (including accountants) consider theirs. Anyway, if justification were necessary, I can quote Sir Frank Gill, President of the Institution of Electrical Engineers in 1922—"Economics is the fundamental problem of the Engineer".

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SECTION D—NATURAL SCIENCES

Presidential Address

(Friday, 22nd November, 1963)

SYMMETRY IN PLANTS

by

M.D. Dassanayake

The parts of a plant, such as the leaves, are in general arranged in a symmetrical way on an axis such as the stem or root, and the vascular tissues within such an axis are also arranged symmetrically. Symmetry of this kind is an obvious characteristic not only of plants but of living things in general.

Two kinds of symmetry that are common in plants are radial symmetry and dorsiventral symmetry. In radial symmetry, similar parts are arranged around an axis so that there is uniformity on all sides. Radial symmetry is common in stems, roots and flowers, both in the arrangement of the tissues within and of the external organs. A transverse section of a root shows the vascular bundles to be evenly spaced in a circle. The xylem forms a somewhat star-shaped pattern, with the phloem groups alternating with the rays. Externally, the branches of the lateral roots are evenly spaced around the main root axis, and arranged in vertical rows which correspond to the xylem rays.

In stems too symmetry is seen in the internal structure. The vascular bundles are evenly spaced and arranged in a circle. In a tree trunk, a cross-section shows the wood forming a circular mass, with the rays running radially through it. Externally, the symmetry shown by the arrangement of the leaves on the stem is apparent even to a casual observer. There are many ways in which leaves may be arranged on a shoot. In one type of arrangement the leaves are in opposite pairs, the successive pairs being at right angles to each other. So there are four vertical rows of leaves, evenly spaced around the stem and separated by angles of 90 degrees. A more usual arrangement is for the leaves to be alternately placed. This arrangement is also regular, and a line connecting the points of attachment of successive leaves forms a helix around the stem. This is described therefore as the helical arrangement.

There is much diversity in this arrangement, and also a regularity, which has attracted the attention of botanists and mathematicians for a very long time, from Leonardo Da Vinci to the present day. In a truly alternate arrangement, the leaves would be placed singly, alternately and in one plane. There would be two vertical rows of leaves, separated by an angle of 180 degrees. In passing from one leaf to the one directly above, one circuit is made around the stem, and in the course of this, two leaves are passed. This type of arrangement may therefore be written down as 1/2. Every second leaf is directly above the one below.

In another type of helical arrangement, in passing from one leaf to the one directly above, one circuit of the stem is made, and in the course of this three leaves are passed. This may be indicated as 1/3. Every third leaf is directly above a given leaf. In a commoner type of arrangement, in passing from one leaf to the one directly above, two circuits of the stem are made, and the fifth leaf is directly above a given leaf. This may be indicated as 2/5. Further types of arrangement of this kind are 3/8, 5/13, 8/21, 13/24, 21/55 etc. The fraction in each case represents the fraction of a circle, i.e. the circumference of the axis, which is traversed in passing from one leaf to the next one above or below.

These numbers form a series, and there is a regularity in this series. It is what is called a Fibonacci Series. The number in the numerator or denominator equals the sum of these numbers in the preceding two fractions. Thus in 1/3, 2/5 and 3/8, $3=1+2$; $8 = 3 + 5$. Also, the denominator of one fraction forms the numerator of the next but one.

The higher fractions in this series tend to become more and more uniform, and approach the value 0.38197, which is equivalent to angle of 137 degrees, 30 minutes, 28 seconds. This is interesting, in that it is what is called the ideal angle, and if the successive leaves are arranged at this angle exactly, then no leaf will be directly above another. The figure 0.38197 also represents what is called the 'golden mean':

$$1 - 0.38197 = 0.61803 \text{ and}$$
$$0.38197 : 0.61803 = 0.61803 : 1$$

Now, if the arrangement of leaves is according to these fractions, such as 1/3, 2/5 etc., then there should be vertical rows of leaves corresponding to these fractions. If it is 1/3, then every third leaf should be above a given one, and there should be three vertical rows of leaves on the stem. So there should be few vertical rows in the simpler arrangements and more in the more complex ones.

There is another way in which the arrangement of leaves may be interpreted. The arrangement of leaves in the older parts of a shoot represents the order in which the leaves have their origin. At the tip of the shoot there is the bud which contains the growing point, the apical meristem. It is here that new leaves arise as the shoot goes on growing upward. The growing point is a dome-shaped mass of embryonic cells, and the young leaves arise as primordia in fixed positions around this apical meristem, where they may be seen with a microscope. If the primordia at the apical meristem are examined, it is seen that no leaf arises exactly vertically above another. But as the shoot matures, it becomes drawn out, and these vertical rows come into being.

Apart from the leaf primordia at the apical meristem, other suitable material for the study of arrangement of lateral organs are the scales in a pine cone and the florets in a composite inflorescence, such as a sunflower head, which is really a shortened shoot. The cone scales and the individual florets are seen to be arranged in a series of helices or spirals. Actually, as may be seen on examining a sunflower head, there are two sets of these spiral curves, starting at the centre and moving out towards the circumference. One set of spirals moves towards the right, in a clockwise direction, and the other moves towards the left, in counter-clockwise direction, and the two sets of spirals intersect at nearly right angles. The younger members of each spiral are smaller than the older, and closer to the centre.

In a given axis, there is a definite number of these clockwise and counter-clockwise spirals, such as 3 and 5, 5 and 8, 8 and 13, etc. If we arrange these pairs of numbers in the form of fractions, they form a series 2/3, 3/5, 5/8, 8/13, 13/21, 21/34, 34/55, 55/89 etc. Here the numerators and denominators form separate series. Also, the denominator of one fraction is the numerator of the next, and this series approaches as its limit the fraction whose value is 0.61803, which is the larger of the two numbers making up the golden mean, the other being $1 - 0.61803$, which is 0.38197, and is the limit approached by the other series. So the two helical systems are evidently related.

All this appears somewhat mysterious, and has led to various notions about the significance of these numbers in relation to biology. But this series is really a mathematical coincidence, with apparently no biological significance. The basis of the types of arrangement is the regular formation of similar organs, i.e. the leaf primordia, similarly situated, and at regular intervals of time, leading naturally to a series of symmetrical patterns. D'arcy Thompson compares the formation of successive leaves to "a bricklayer building a factory chimney: he lays his bricks in a certain steady, orderly way, with no thought of the spiral patterns to which this orderly sequence inevitably leads".

What determines the particular, regular order in which leaf primordia arise at the apical meristem? According to one view, when there is a primordium at one point at the apex, this inhibits the formation of another primordium close to it; the next primordium does the same, and this leads to the regular spacing of primordia around the apex. This inhibition is by means of a specific chemical substance, which is produced by a leaf primordium, and which inhibits the formation of other leaf primordia in the immediate neighbourhood. So new primordia can arise only in gaps between older leaves, where this inhibition is least. The apical meristem also produces a substance which inhibits the formation of new primordia, close to it. This inhibition by existing primordia and the apical meristem leads to the regular spacing of primordia around the growing shoot apex. The degree of inhibition, the size of primordia and other factors connected with growth at the shoot apex would determine the different types of leaf arrangement.

New primordia actually arise in the largest gaps between existing ones, where sufficient space becomes available as the apical meristem grows in length. Around the apical meristem there is a number of gaps between the primordia of the top cycle. As the shoot apex grows, these spaces enlarge, and become successively available for the formation of new leaf primordia. This is the view of M. and R. Snow. The Snows have actually carried out ingenious experiments involving very delicate operations on the minute apical meristem in support of their views.

Wardlaw suggested that the position of new primordia is governed by tensile stresses operating at the shoot apex. When a leaf primordium forms, a tangential tensile stress is set up in the apical meristem, above the axil of the primordium. The next primordium forms only in a position where this stress is at a minimum. This is actually the position where the largest unoccupied space becomes available, above the general level of the older leaves. So this view is not incompatible with those mentioned earlier. According to Wardlaw, the apical region of the shoot and also the young leaf primordia each constitutes a growth centre, with a surrounding physiological field. New growth centres arise only in positions which are outside these existing physiological fields.

In the dorsiventral type there is only one plane of symmetry. Most leaves show this type of symmetry, being divided into roughly equal halves by the midrib, while the upper and lower surfaces are different. This types of symmetry is characteristic of structures growing under conditions where the environment is a symmetrical, a leaf, for instance, having light falling on it from above, but not from below. In general, this type of symmetry occurs in organs growing horizontally, not vertically.

It is interesting to note that, although a leaf is a dorsiventral structure, a bud, which arises in the axil of a leaf, develops into a radially symmetrical shoot. Dorsiventrality seems to be imposed on a leaf at a very early stage, by the apical meristem. If an incision is made between the very young leaf primordium and the apical meristem, so as to free the leaf primordium from the influence of the apical meristem, then the leaf primordium may grow out into a structure that is radially symmetrical.

The flowers of many plants are radially symmetrical, but some plants have dorsiventral flowers. The left and right sides are similar, but the upper and lower halves are different. In some of these plants, if the flower is made to develop in a vertical position, or kept turning round during its development, it can be made to grow into a radial flower. But in most flowers it has not been possible to alter the dorsiventrality by any such means.

In many plants, horizontally growing twigs and branches are dorsiventral. They are often flattened in the dorsiventral plane. This effect is more marked where the leaves are of different sizes. In Selaginella, for instance, there are four rows of leaves. The two on the upper surface are smaller, and there are two lateral rows of relatively larger leaves.

Some ferns have dorsiventral shoots, such as, for instance, *Polypodium vulgare*, which has a horizontally growing rhizome. In the rhizome of this fern, the apical meristem is at the tip of the shoot. Leaves are borne on the upper surface of the shoot only. Leaf primordia form in an orderly sequence on the upper surface, alternately on the left and right of the apical meristem. Roots form only on the lower side, never on the upper, while buds form in a median-lateral position, between the positions of the leaves and the roots.

The positions of these three types of organ therefore are fixed, by something that prevents the formation of roots on the upper surface and leaves on the lower surface of the rhizome. Assuming that chemical substances induce or inhibit the formation of leaf primordia, possible explanations for the absence of leaf primordia on the lower surface of the rhizome are (*a*) the presence of some substance here that inhibits leaf formation, (*b*) the absence of a substance here that is essential for leaf formation or (*c*) a combination of both. There may be some transverse polarity in the protoplasm of the cells which brings about the unequal distribution of these substances. This dorsiventral polarity in the protoplasm may be genetically determined, and perhaps also related to the horizontal habit of the rhizome.

It has been possible to experimentally alter this polarity and cause leaf primordia to arise on the lower side of the apical meristem, but only temporarily.

In some plants the shoot begins as a radial structure, which changes during the course of its development to dorsiventrality. In the fern *Pteridium aquilinum*, the very young plant has radial symmetry, and grows erect. Very soon, the apical meristem stops growth, and two buds arise from opposite sides of this. These then grow out into dorsiventral shoots, and the adult plant has dorsiventral symmetry. It has a creeping rhizome, which bears leaves on its upper surface only.

What are the causes of organic symmetry? This leads us into a field to which morphologists, physiologists and morphogeneticists have given much thought, particularly in recent times. The causes of symmetry in living organisms is by no means fully known, but in attempting to discover these causes we have to determine how symmetry has its origin in the course of development. In shoots, for instance, we have to look at what takes place at the embryonic regions in order to determine how symmetry originates. In the higher plants, it is at the apical meristem that the symmetry of the arrangement of leaves and the internal tissues has its origin, and various attempts have been made to discover the causes of this symmetry.

Sachs, at the end of the last century, attempted to discover the causes underlying the form and structure of plants. In his view, differences between organs such as leaves, buds and roots are due to differences in their chemical composition. The differences are present at the time the organs have their inception and, according to its chemical composition, a primordium develops into a leaf, bud, etc. This concept, with modifications, is held even at present, and attempts have been made to discover these various organ-forming substances, and to account for their distribution at the apical meristem to form a pattern, which leads to organic form and symmetry.

SECTION E: PHYSICAL SCIENCES

Presidential Address
(22nd November, 1963)

INDUSTRIAL HAZARDS

by

C. SATKUNANANTHAN

I am grateful to you for the honour you have done me in electing me your President for the current year. I believe you have done me this honour in recognition of the importance of the subject of Occupational Hygiene, especially in the present state of industrial development of our Country. It is one of the newer subjects and has been developed during the past forty to fifty years. It embodies the disciplines of chemistry, engineering and medicine; University post-graduate courses in the subject are designed for the Chemist, Engineer and Physician, each specializing in his own aspect while learning something of the other two. The administration of the subject in industry needs the team-work of all three. In Ceylon, the subject comes under the statutory purview of the Factory Inspectors of the Labour Department and the Government Analyst while the Medical Officers and Research Officers of the Labour Department act in an advisory capacity.

The urgent need for the rapid industrial development of our country for our economic progress has been recognised for a long time. In his presidential address in 1948, the late Dr. A. Kandiah outlined a scheme for the training of personnel for Scientific and Industrial Research. Subsequently, our own sectional Presidents have emphasised the need for Industrial Research and for the training of manpower for the development of our country. Several new factories have come into being in the past few years; these produce a variety of goods and are staffed mostly, by trained Ceylonese. The time is now opportune for us to consider the possible hazards these new factories present to the health of the nation.

Historical

Industrial hazards have been recognised for a long time; for instance, it has been known for centuries that excessive dust inhalation can produce serious pulmonary disease which has been called in the various dusty industries as miners' asthma, miners' phthisis, grinders' rot, etc. The phrase, "mad as a hatter", arose as a result of workers being poisoned by the mercury nitrate used in the felt hat industry. The symptoms of the disease include emotional disturbance, anxiety, depression and, even personality changes—hence the rather unkind reference to madness.

The dangers of the industrial exhaust gases were recognised as early as 1661. In that year, John Evelyn, an Englishman presented a petition to King Charles II, complaining against the pollution of the atmosphere of London by arsenical, sulphurous and other vapours and suggesting that the brewers, dyers, lime-burners, soap and salt-boilers who were responsible, be removed away from the city. He even attributed the annual decease of 10,000 in London's population to this fouling of the atmosphere.

Hazards

Two distinct groups of the population are exposed to industrial hazards.

1. Those working in the factory.
2. The general population (including animal and vegetable life) outside the factory.

The workers in factories form a special group of the general population; they are normally in the 15-60 years age-group, are healthy—otherwise they would not be at work—and are exposed to the hazards for eight hours a day. These hazards may arise from the machinery they operate, from a high level of noise, from fires and explosions and from the fouling of their working environment by poisonous or noxious gases, fumes or dusts.

On the other hand, the general population consists of people of all ages, the healthy and unhealthy and is exposed to the hazards 24 hours of the day. The hazards may arise from pollution of the atmosphere and waterways by industrial exhaust gases and dusts and effluents and also from fires and explosions.

The London Fog of December 1952

How differently these two groups of people react to a particular environmental hazard is illustrated by the morbidity and mortality during the London fog of 1952. The fog lasted for four days from December 5th to 8th. The number of deaths per day during this period was approximately 900 compared to the normal 300. The increased morbidity and mortality were among those already affected by chronic illnesses. To the great majority of normal healthy individuals, the fog was little more than a nuisance. One of the harmful agents was identified as sulphur dioxide. This is one of the products of combustion of fuels like coal, coke and oil which contain amounts of sulphur varying from one to four per cent. The maximum amount of sulphur dioxide found in the atmosphere during the

four days was 1.3 parts per million while the maximum allowable concentration of sulphur dioxide within a factory is as high as 10 parts per million. It is thus clear, that while exposure to 10 parts per million of sulphur dioxide for eight hours and 1.3 parts for twenty four hours may be safe for the normal healthy individual, it would be dangerous and even fatal for the old or the sick. Of the 4000 people whose death may be directly attributed to the fog, some may have been adversely affected even by a concentration of sulphur dioxide smaller than 1.3 parts per million.

One reason for implicating low concentrations of sulphur dioxide in the London fog disaster is the fact that persons with chronic bronchitis obtained relief in fogs when low concentrations of ammonia were added as a neutralizing agent. This palliative was suggested as a result of an observation made at the Smithfield cattle show held during the fog. It was found that cattle whose stalls were not cleaned to eliminate the ammoniacal excreta fared better than the prize cattle whose stalls were regularly cleaned. The British Medical Journal suggested editorially that relief could be obtained in private homes from an indwelling pig or a damp baby.

Effects on Plant Life

Industrial effluents and exhaust gases, fumes and dusts cause great damage to plant life. The damage to plant life from effluents discharged haphazardly without proper treatment into fields and waterways is obvious. Dust may affect the amount of light received by plants due to the loss of transparency of the atmosphere and by forming a screen on the leaf. It may also clog the stomata; the average smoke particle has a width of approximately 0.8μ while the width of the stomata is about 2 to 4 μ.

Dust, fumes and gases may also have a direct physiological effect on the plant, due to their toxicity. For instance, 0.01 – 0.06 part per million of sulphur dioxide has been found to have an adverse effect on rye grass. Most of us are aware of the damage done to plant life by the hydrogen chloride discharged by the Le Blanc sodium carbonate factories in Britain over a century ago. Today, similar damage is being done to jungle and other plant life by the chlorine discharged by the caustic soda factory at Paranthan.

Dusts, fumes and gases may also indirectly affect plant life through their action on the soil.

Types of Industrial Poisoning

Industrial poisoning, like ordinary poisoning, may be either acute or chronic. The hazard of acute poisoning is most often, though not always, readily recognised. It is the result of contamination of the environment by poisonous vapours and gases or of improper handling of poisonous material, for example insecticides. Occasionally the hazard is not recognised, as is illustrated by an unfortunate incident that occurred at Kalutara a few years back. The liquid wastes in a factory processing rubber latex were run into a septic tank for bacterial purification, before eventual discharge into waste land. Workers had been instructed to clean the tank; the danger of the hydrogen sulphide in the tank, apparently, was not recognised and the workers were neither warned nor provided with protective equipment. One worker removed the small man-hole cover, lowered a ladder and descended about half-way down the tank. No sooner had he started stirring up the liquid in the tank with a long pole than he collapsed and fell into the liquid which was about three feet deep. One after the other six others went down the tank to help him and all of them met with the same fate. Only the last man survived; the other six succumbed to the effects of hydrogen sulphide. Twenty-four hours after the tragedy, the amount of hydrogen sulphide in the tank was 28 parts per million; at the time of the incident it would have been very much more. The maximum permitted in industry is 10 parts per million. The danger of hydrogen sulphide lies in the fact that it deadens a person's sense of smell in a few seconds; therefore, a person may continue to breathe it in, inspite of its very disagreeable smell. In passing, I may mention the ever present hazard of hydrogen sulphide in laboratories; there have been a number of cases where students and laboratory workers have been overcome by this gas due to inadequate exhaust ventilation of fume cupboards. The use of ethyl-ammonium ethyl dithiocarbonate instead of hydrogen sulphide in qualitative analysis has been suggested recently. It is said to have the advantages of being non-toxic, stable and possessing only a faint and not unpleasant odour.

Chronic poisoning is the result of exposure to the hazard for a long period; and takes a long time to manifest itself. Sometimes the symptoms develop after the exposure to the hazard has ceased. Industrially, chronic poisoning is a much more difficult problem than acute poisoning.

Dust diseases

Exposure to dusts and fumes causes four distinct types of illness:—

1. the pneumoconioses, which are caused only by dust inhalation,
2. the systemic toxic effects caused by either inhalation or ingestion of certain dusts, such as lead and manganese,

3. metal-fume fever caused by inhalation of certain metallic oxide fumes like zinc oxide, lead oxide and magnesium oxide,
4. allergic reactions like hay fever, resulting directly from inhaling pollen or other organic substances.

Pneumoconiosis

The term, pneumoconiosis (literally, a lung containing dust) was originally used to describe illnesses where the lung had been seriously damaged by dust. Now, it carries a broader meaning and includes all pulmonary manifestations of dust inhalation, whether the dust is injurious or innocuous. Silicosis, asbestosis and byssinosis are different forms of pneumoconiosis caused by different dusts. In Ceylon we should be particularly careful about the hazards presented by dusts and fumes because of the increasing number of industries that are producing them. A large number of mechanical stone-crushers is now used all over the country to crush stone and granite. Some of these do not have any system of removing the very fine silica dust that is produced; there are always clouds of fine dust in the working environment and the worker is exposed to the risk of silicosis with continued exposure to this dust. The American Public Health Association defines silicosis as "a disease due to breathing air containing silica (SiO_2), characterized anatomically by generalized fibrotic changes and the development of miliary nodulation in both lungs, and clinically by shortness of breath, decreased chest expansion; lessened capacity for work, absence of fever, increased susceptibility to tuberculosis. . . . . .". Granite which is quarried and widely used in the country contains feldspar (70%), quartz (25%) and mica (5%). Quartz is a form of silica (SiO_2) while feldspar and mica are silicates. The latter, though not harmless are not so dangerous as quartz.

Inhalation of asbestos dust and cotton dust over a period of time could produce asbestosis and byssinosis respectively.

Cement dust consists mostly of silicates which, as I mentioned, are not so harmful to human-beings as silica. Though necessarily a dusty industry, the modern cement industry with its efficient dust removal systems has a good health record. But, where the dust removal systems are not up-to-date, the dust becomes a nuisance to the general population and causes positive harm to plant life. Most of us are aware of the dust nuisance created by the Cement Factory at Kankesanturai and the complaints by farmers of damage done to their crops during the last ten years. Fortunately, modern electrostatic precipitators have now been installed to remove the fine dust. One wonders why these were not installed when the factory was erected, especially as the factories erected in the West about the same time were equipped with them.

Lead Poisoning

Lead is used in linotype printing presses and in industry for the manufacture of accumulators, paints and lead tetraethyl. There is much greater danger of poisoning from inhaled than from swallowed lead dusts. It has been observed that galena-lead sulphide ore-miners do not suffer from lead poisoning while the men who smelted the concentrates and inhaled lead fume had occasional attacks of colic. In any mine or factory processing lead, the hazard is greatest at points where lead fumes are evolved. Control measures should, therefore, be focussed especially on jobs in which lead fumes of fine particle size may be inhaled. The toxicity of a given lead compound depends on its solubility and the fineness of the particles; the finer the particle the greater the probability of its deposition in the alveoli and more quickly does it dissolve. The optimum size for alveolar deposition of lead is about 0.5 micron. From the alveoli, the lead passes into the blood stream. No symptoms of lead poisoning appear when the amounts of lead are small. Some of the lead is excreted and the rest is deposited in the bones. If exposure to the hazard is prolonged, large amounts of lead may accumulate in the bones, but the individual may be apparently healthy. A blue line on the gums may be noticed due to the precipitation of lead sulphide by the hydrogen sulphide arising from septic processes in the teeth and gums. Where the oral hygiene has been good, the blue line may not appear. During times of stress, for instance, fever, the accumulated lead is released into the blood stream and the symptoms of acute lead poisoning develop.

Recently, a six-year old boy was admitted to a hospital in Colombo with a history of intestinal disturbances and general debility. The medical officer remembered that the boy's sister was admitted to hospital a few weeks before with a similar history, but gravely ill and had died soon afterwards. He suspected lead poisoning, which was confirmed by laboratory examination of the urine and blood and by X-ray photographs of the bones. The boy recovered after treatment with calcium versenate. The source of the lead intoxication was investigated. It was found that in an open space close to the children's house, where children of the neighbourhood play, some persons were engaged in recovering gold and silver from dross and sweepings. At one stage of their recovery process they used molten lead without any safeguards whatever. It was also found that a number of children living in the area had died during the past few years. The cause of their death apparently could not be ascertained and the area had earned the reputation of being haunted. No resident, except perhaps the persons carrying out the process, stayed on for a long time in the area.

The parents of the two children were advised to hospitalize their younger child, who was apparently well, for investigation. Urine analysis revealed excessive amounts of lead and the child was given proper treatment with calcium versenate. In another instance, two children in a family fell ill with lead poisoning and one died. They lived in Colombo, in one of three tenements with a common back-garden. The occupier of the adjacent tenement was engaged in repairing old accumulators in the premises. Lead fumes from the molten lead used in this process were the source of the lead intoxication.

Children die of lead poisoning, the cause of the lead intoxication is traced to the unsafe processes, but the processes apparently go on without modification. Children are much more susceptible to lead poisoning than adults. The adults who have been exposed to the hazard in the above incidents, may suffer from lead poisoning later on.

Metal-fume fever

Metal-fume fever is a transient disturbance that results from exposure to heavy concentrations of metal fumes like lead oxide, copper oxide, magnesium oxide, zinc oxide and manganese oxide. It is a form of acute rather than chronic poisoning, but it is convenient to consider it here under dusts and fumes. Usually, the victim experiences chills and high fever after 2-8 hours of exposure; next day he feels weak but can attend work. According to Professor Drinker, Professor of Industrial Hygiene at Harvard University, the cause of this peculiar illness is, probably, the absorption of protein material resulting from the action of the inhaled fume particles on the tissue of the respiratory passages.

Allergic Reaction

Allergic reactions like hay fever and dermatoses are produced by a number of organic dusts. Sensitivity varies greatly and unpredictably with the individual. It is unnecessary for the dust to reach the alveoli in order to produce the reactions, though probably a fine dust able to reach the alveoli will accentuate the reactions. Breathing the dust from dried castor-seeds could produce a severe reaction. The irritant in this dust is ricin, a powerful protein poison. A plant in the U.S.A. extracting oil from castor-seeds had excellent control measures and there was no dust within the plant to bother the employees; but enough dust escaped to affect employees in the adjoining foundry. In another instance, also in the U.S.A., men two miles away from such a plant were affected by the dust and the plant was closed permanently by court order.

Effects of particle size of dust

The harmfulness of a particular dust depends on its particle size which determines its ability to penetrate deep into the lungs and settle down. When dust is inhaled, the particles about the size of a pollen and larger i.e. about 15 microns and larger, are caught up in the nasal passages or at the back of the throat. The smaller ones, about 1 to 15 microns in size, reach the trachea, bronchi and bronchioles but are removed by ciliary action, eventually reaching the mouth where they are spat out or swallowed. Particles which are about a micron or less in size reach the alveoli where there are no cilia. The smaller of these particles—about 0.3 microns in size, the lower limit of microscopy—act like molecules of the transporting gas and may be breathed out. The larger ones settle in the alveoli where they are engulfed by phagocytes. These pass into the lymphatic system and are deposited at the tracheobronchial lymph nodes, eventually producing the various forms of pneumoconiosis. The optimum size of silica dust for alveolar deposition appears to be about 1 micron.

The efficiency of dust removal systems in industry is usually expressed on the basis of weight, the weight of dust removed being given as a percentage of the weight of dust originally present. This is misleading as even an efficiency of 99.9% in a dust removal system does not mean an elimination of the actual hazard. Suppose we have two particles of the same dust, one 10 micron and the other 1 micron in diameter. The former would weigh 1000 times the latter and its removal would mean an efficiency of 99.9% on the basis of weight. But the potentially more harmful 1 micron dust particle, which is also more difficult to remove, is still there.

Legislation

The Factories Act lays down rules regarding the safety, health and welfare of the workers, which have to be observed in factories and imposes restrictions on the hours and times of work of women and young persons. The Factory Inspector is the statutory authority under the Act to ensure that the provisions of the law are complied with. Neither he nor the Department of Labour can of course, decide whether there is a breach of the law in any particular case; that would be a matter for the Courts of Law, if legal proceedings were taken. But the Factory Inspector could be consulted about safety, health or welfare conditions which are felt to be unsatisfactory and perhaps illegal; he may be able to assist in making improvements even if there is no clear breach of the law.

The law specifically lays down that no person shall enter a tank or confined space containing dangerous gases, unless he is attached by means of a belt to a rope held by someone outside and unless he wears a suitable breathing apparatus. It is also obligatory for a factory to remove all fumes and dusts within the premises. However, inspite of these provisions of the law, the incidents I referred to before, occurred and lives were lost due to hydrogen sulphide and lead poisoning. The machinery for the enforcement of the law is obviously inadequate. The position is likely to grow worse with the expanding of our industries. In his latest Administration report, the Commissioner of Labour refers to the difficulty of recruiting trained and qualified staff to the Factory Inspectorate. If our programme of industrial development is to proceed without endangering the health of the nation, an expanded Factory Inspectorate is essential.

The industrial worker who suffers a patent and immediate injury say, a broken arm, while at work may not have difficulty in obtaining his legal compensation from the employer; on the other hand, a worker exposed to dusts and fumes, whose effects do not manifest themselves or become disabling till some years after the exposure, may find it impossible to get any relief by way of compensation because of the limit set by the law to the time before which any action should be taken. This is illustrated by a recent House of Lords decision (Cartledge and others *v*.E. Jopling & Sons Ltd.) Lord Reid said that the evidence in this case was that a person, who was susceptible to pneumoconiosis and inhaled the noxious dust over years would have suffered substantial injury to his lungs maybe long before his injury could be discovered by any means yet known to medical science; we had the absurd result that even if workmen were able to have X-ray photographs at regular intervals, a large part or even the whole of the period of limitation would have elapsed before they could, even with the best possible advice, instruct the raising of an action.

The trial judge held that the pneumoconiosis from which plaintiffs suffered, had been caused by the employer's breach of statutory duty, but as the cause of action had accrued in each case more than six years before the issue of the writs, the action failed. In giving the judgment of the House of Lords, affirming the trial judge's decision, Lord Pearce said "It was to be hoped (therefore) that in future, their Lordships would not have to deny relief in such cases as these to plaintiffs who, having good causes of action, had lost them through no fault of theirs".*

I may also mention that there have been instances of Welsh miners, who passed the physical examination for enlistment in the British Army and fought in the trenches through the first World War (1914-1918) and came back to Britain and died of Silicosis.

It may surprise most of you to know, that there is no specific legislation in Ceylon to prevent the pollution of the atmosphere and waterways by the discharge of fumes, dusts, gases and effluents

*The law in England has now been amended as suggested by Lord Pearce.

from factories. In Britain, the Alkali Works Regulation Act was enacted in 1863, to prevent the hazard of the hydrogen chloride that was then being discharged into the atmosphere by the Le Blanc sodium carbonate factories. The original Le Blanc process provided for the condensation of all the hydrogen chloride; but the factories set up in Britain allowed some of it to escape into the air. In 1862, this amounted to 1000 tons a week and no vegetation grew for miles round the factories. The Alkali Act made the condensation of 95% of the hydrogen chloride compulsory. Eleven years later in 1874, the regulation was made more stringent and flue gases were required to contain no more than one-fifth of a grain of hydrogen chloride per cubic foot—i.e. about 0.5 part per million.

That was in Britain, in 1863 and 1874. Today in Ceylon, the caustic soda factory at Paranthan discharges, with impunity, tons of chlorine into the atmosphere. It will not be long before the jungle and cultivated crops near the factory are destroyed by the chlorine. The chlorine harms the vegetation directly, by its toxicity and indirectly, through the soil. It may change the soil population, and in particular, the nitrogen fixing bacteria may be eliminated. It may also delay the break down of organic material and thus impair the cycle of renewal. So that even if the destruction of the jungle by the chlorine is considered beneficial in that, land will be thus made available for cultivation of food crops, no cultivation would be possible unless the discharge of chlorine is stopped and the already deteriorated soil is properly prepared.

If the original plan to set up a D.D.T. plant at Paranthan, using the chlorine from the caustic soda factory, had been adhered to, today's chlorine hazard would not have arisen. Although the caustic soda factory is today producing only 30-40% of Ceylon's needs of caustic soda, the factory cannot contemplate any expansion of production in view of the increase in the chlorine hazard. Production of one ton of caustic soda means the simultaneous production of 0.88 ton of chlorine and the latter has little or no market. At least some of the difficulties faced by the caustic soda factory today, are due to that hasty and ill-considered decision not to manufacture D.D.T.

The relevant section of the British Alkali Act requires that in any work where chlorine is used or made, the best practical means must be taken to prevent its escape from any apparatus, and to prevent its discharge, directly or indirectly, into the atmosphere. Where discharged, it should be rendered harmless and inoffensive.

I would make a strong plea for better co-ordination in our industrial planning and development and for the early enactment of legislation for the prevention of atmospheric pollution. We do not tolerate any adulteration of our food; we are very particular as

to what preservative, if at all any, should be added to our food and in what amounts; we are fastidious about the use of additives to improve our food. We have our own Food & Drugs Act to prevent the adulteration of food. But we have no legislation to prevent the pollution of the very air we breathe though we breathe about 16 times a minute right through the 24 hours of the day.

We have made vast strides in public health during the past 30 years. Our life expectancy at birth has increased from 32.7 in 1922 to 60.3 in 1954. This has been achieved more by a reduction in our death-rate rather than by an increase in our birth-rate. But the latest administration report of the Director of Health Services points out that though the mortality rate is decreasing, the morbidity rate is increasing. All this would mean that we are tending towards an ageing and unhealthy population. We must, therefore, ensure that our programme of industrialisation does not endanger the health of the industrial worker and the general population outside the factories and increase the problems of an ageing and unhealthy population. As Mr. W.A. Damon, the former Chief Alkali Inspector of Britain has said "the development of industry is inevitably accompanied by some loss of amenities, which may include a degree of air pollution. The manufacturers must, however, employ the best practicable means whereby such pollution and its effects are minimised. In planning new processes, the provision of suitable control measures should be regarded as one of the first essentials. Good equipment of ample capacity should be installed at the outset. The replacement of an inferior device is likely to prove more expensive than the provision of a better one in the first instance would have been, and a capacity that is only just sufficient at the outset will not cope with the increased output that is normally hoped for in the future".

About one hundred and seventy-five years ago, Voltaire said: "the price of freedom is eternal vigilance"; we may with equal truth say, today, "the price of industrialisation is eternal vigilance".

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SECTION F—SOCIAL SCIENCES

Presidential Address
(23rd November, 1963)

"ON LOOKING INTO 1980"

by

C. SURIYAKUMARAN

'On Looking into 1980' is the subject I have chosen for the address I am privileged to deliver before you today. At first when the title came to mind I expected that I would have to take myself to the year 1980 and look back at events that were still to occur. Somewhat in the fashion of Gulliver's Travels, except that in my case I would be using a time and not space dimension, I felt that the enormity of a present problem would be brought down to size (or vice versa) by viewing it back from a hypothetical future date.

I have found myself in little need of an apology therefore, to look forward towards possibilities of distant prosperity and to visualise what in actual fact such a prospect may look like. And so I have proceeded to project my thoughts, insome way, into a future sufficiently distant to be adventurous, but not too far away to be indiscernible. Unfortunately, unless one could count astrological predictions, there is no Chapman's Homer nor economic Nostradar mus to bring this unknown right before us in all its actuality. My endeavour today is, therefore, to essay some idea of what ou- present problems will look like about the time we are getting into the eighties. If the result of this exercise is a bright picture as to the future the pleasure would be rewarding; if it were dismal the exercise may perhaps be a useful means of timely self-correction. Perhaps, it has parts of both.

It is only proper that I clarify the scope of my subsequent observations at this juncture. Firstly, I refer only to this country. The second clarification arises from the fact that one could look at a number of things, the state of morals, the state of politics or of life in general, and try to see what any one or more of these would look like some years hence. The very idea of crystal gazing, even in one field, is so hazardous, that I need hardly state that I should confine myself just to that field with which I may however imperfectly be somewhat familiar. My intention, therefore, is to take a look at our economic prospects, to see whether our present problems are real or just shadows, to inquire whether it is these problems or others that will loom in the next decade, and generally to examine

whether we would succeed or fail in what is known as our development objectives. Even here I would certainly not pretend to be comprehensive but would only touch on some aspects that are of outstanding significance and perhaps admit of easy description.

Much as there is an element of rashness in this exercise, I feel equally strongly that some highly controversial issues and some ostensibly insurmountable difficulties in certain fields which exist today in our economic problems, tempt one strongly to appraise the relevance of these issues and the rationale in these difficulties. With this prologue, all of which is intended as much to be an apology for daring to visualise, as an outline of the basis for undertaking it, I shall proceed.

II

It would be wise to start with a brief stock-taking of the present and some of the major known trends in the economic structure as it is. First, our population. From an earlier projected figure of a little over 11 million for 1962 it is expected that we would have reached 13.2 million by 1968 and 18.7 million by 1980. The available work force, i.e. those within working age and physically capable of work, is expected to rise from a figure of nearly 4 million in 1962 to 4.7 million in 1968, and 6.7 million in 1980. Our Gross National Product has been increasing in recent years at an average annual rate of 3.4 per cent and a per capita rate of .4 per cent. The estimated rate of increase in the Ten Year Plan for the corresponding terms, was nearly 6 per cent gross and 2.9 per cent per capita. This means that in order to cope with the population increase our Gross National Product should rise, on the basis of the current meagre .4 per cent per capita annual increase, to something like Rs. 11.7 million in 1980; and on the basis of the Plan per capita rate to about Rs. 19.7 million. In other words, even on the present slow rate of growth, G.N.P. would have to double itself from the figure of 1962, and on the basis of the Plan would have to treble itself, if the expected population increases and employment for the future work force are to be satisfactorily met.

There is another facet of the 1980 picture which is worth setting down. On the basis of scales of consumption of recent years, a set of figures could be assembled showing the scale of expansion required in the future in some of the major commodities and services in the economy. These are tentative estimates though based on reasoned assumptions,* but they give some idea of volume

*Acknowledgement is here made of valuable assistance rendered by Mr. V. Ambalawanar, Research Officer, Department of National Planning, in undertaking a considerable amount of statistical work for the whole of this paper. It involved collation and computation on varying assumptions and bases as well as help in testing for validity of the projections so made. The responsibility for using any of these results is, of course, mine.

changes even in the background of modertae rates of growth. It must be noted that the information I am about to give is not of production but of total consumption.

Rice, showing a total consumption of 21 million cwt. in 1961 would reach 36.6 million cwt. in 1980.

Sugar would go from 190,000 tons in 1961 to 331,000 tons in 1980

Onions would go from 2.2 million cwt. to 3.8 million cwt. during the same period.

Potatoes would go from 1.3 million cwt. to 2.2 million cwt. during the same period.

Chillies would go from .75 cwt. in 1961 to 1.3 million cwt. in 1980.

Fish would go from 3.4 million cwt. to 6 million cwt. in the same period.

Salt would go from 68,000 tons to 119,000 tons during the same period.

Textiles would rise from 170 million yards to 615 million yards during the same period.

Cement would go from 296,000 tons in 1961 to 1.2 million tons in 1980.

Bricks would go from 1 thousand million to 4.3 thousand million over the same period.

Paper from 15,000 tons to 51,000 tons over the same period.

Electricity from 319 million kilowatts to 1,825 million kilowatts in 1980.

Public passenger transport from 3,700 million passenger miles to 12,700 million passenger miles over the same period.

Road and rail freight transport from 857 million ton miles in 1961 to 3,146 million ton miles by 1980.

It is clear that there are going to be big increases in consumption all round, including the field of basic consumer commodities. In the case of some, the stepping up of consumption is about twice present consumption. For a large number of these items the expected increase is 3 or 4 fold, and is even 6 fold in certain cases. When we consider that actual domestic production in a number of these is only a fraction of current consumption, one might say by way of a broad generalisation that we need to see something like a 7 per cent rate of growth per annum in national income in order to sustain per capita living standards at only a little more than the present in 1980. Against the present growth rate of 3.4 per cent, this prospect of a 6-7 per cent rate and of a national income which within 17 years from now is 3 times the present, may appear to be difficult to conceive.

This, in fact, is my point of departure for my exercise in speculation into the future. Is the economy likely to grow at such a rate in the ensuing years that this picture will be realised by 1980? Put in a manner that may perhaps be more easy of discussion, what are the potentially limited and unlimited areas and factors of rapid growth within the economy as they appear now, and what in both these fields are the obstacles, real or imaginary? If the obstacles are imaginary and the under-lying directions and pace are right, then we have not much to bother about at present. It is just as likely, however, that the obstacles are there not for physical reasons, if I may say so, but because of lack of policy approaches that should have been adopted or because of faulty policy approaches that should not have been adopted.

I think it is best to approach this question of the future by realising that in the end most important things have a way of being solved on the right lines. This should follow from the view that unless the implications of a situation are foreseen and right policy adopted, the development of that situation to critical positions will make the right policy self-evident. Theorising and intellect notwithstanding, events inevitably serve as our ultimate educators. A country is thus never lost in its race for achieving national goals. So, when most of us criticise past trends or pace in development, in a sense we are criticising the failure to adopt right policies *in time*—and of course this is valid criticism. Sometimes we ourselves stall adoption of right policies by recasting crises when the situations are not fertile enough to give birth to crises! I shall not go into specific examples at this point.

Now, for the thinks which we think are apparently standing today in the way of rapid growth—and my own ability to predict a reasonable 1980 picture.

If one may paraphrase practice into theoretical language, one may say today that Ceylon has adopted certain policies that are clearly growth-oriented. The idea of import substitution in respect of consumption or wage goods (agricultural and industrial) with less emphasis on capital goods, closely resembles ideas of 'balanced' (growth based on the mutual sustenance of demand for various consumer commodities by the creation of a complementary system of consumer-based industries. There is indeed oral recognition of the importance of specific large sectors, and of exporting in the future, but not in policy steps as far as they have been taken so far. In a sense, the historical availability of a very large export sector may be held to justify the immediate absence of new large export sectors in practical policy. There is also recognition of the importance of the role of savings in capital formation in Governmental policy. There is recognition, too, of the futility of purely monetary measures like stepping up consumer demand to serve as a means and agent of development, although for social and other reasons a considerable amount of money disbursement for consumption does take place. There is, finally, some recognition of education, again with a possible lopsididness in actual implementation, as a means of production.

It is clear, however, that all this has still had little impact on growth—past estimates work out to .4 per cent per per capita per annum. Now, it has been noted that this growth has been largely contributed by sectors into which the new capital investments of recent years have not gone. The question that has been asked is whether the new sectors are, therefore, all deadweight. In fact, this charge has been made. Is it the case then that these new sectors will never be able to step up the rate of their own output? After all these years of investment, therefore, will 1980 be a poor year to live in? I think that some understanding of this would be possible if we were to understand the process of growth in its technical aspect. The process of development is essentially and basically not in the availability of factors of production or capital or in demand creation. These are the instruments. The growth process is fundamentally one of creating productive capacity in various forms and utilising this created capacity. The assembly of various factors and skills to give the shape of a factory or a multi-purpose scheme, would be examples of this capacity creation; maximising output through these as also from old capcity that already exists such as exists such as existing paddy lands, would be illustrative of utilising created capacity. The term'take off' of which you have heard, cannot thus be understood in a generalised sense. One cannot take off by just saving or by the mere possession of factors of production. We have to put these together. Not only that—having put them together they have to be made to yield their physical potentials. This, especially the second, takes time—more time in some societies and less in others, depending on historical, geographical and other reasons—but it takes time. This time lapse is the period taken to develop sufficient 'thrust' before the economic machine gets used to puring out commodities in full quantity. Now, this is not an apologia for our present position. It is not certain that time-lapse alone could be allowed to explain some of our past poor performances. Yet in terms of 1980 one must see the present as belonging essentially to this phase which is occupied with the building up of sufficient thrust before created capacities can be fully put to use. In this sense there is no doubt that the requisite thrust will in time be developed. When it is so developed, it would contribute to a raising of the rate of growth in G.D.P. almost by definition because it would be additional to the contribution of the old sectors which are the main base for the present growth rate. The time lapse required thereafter in beginning to use fresh capacities would be even shorter than in the near future, with the result that the rate of rise in G.D.P. would be fairly cumulative.

Now, there are, despite everything, clear signs of this happening. Resource mobilisation, pre-planning, constructional performance, production organisation, skilling and management approaches, which are the key areas through which growth processes would succeed, are all showing the beginnings of greater performance efficiency. In fact, it is easier to look from this point of view at 1980 than, say, 1968, for one cannot be as sure that changes will be speedy enough to register adequately by 1968 as by 1980. It is easier to see that by 1980 we should (speaking as human beings with sufficient justifiable trust in people's thinking and urges) have long reached an advanced stage of competence in related ideas of modern management and production techniques both in directly productive and in so far as they are relevant, in indirectly productive activities. One could say as a matter of certainty, that these new sectors in Agriculture, Industry, Power, Construction and Transport, are all on the way to very rapid spurts in output performances.

By the time we near 1980—perhaps well before it—the present enigma in which new investment is dominantly in the new sectors while contribution to G.D.P. is from the established sectors like the plantations, will long cease to exist. In that future period the increment to national income from the plantations would not be as relatively high as hitherto, either as a percentage of total national product or in terms of relative rates of growth of the sectors. It is the new sectors that will be responsible for the high rate of increase in G.D.P. What we are witnessing now is, therefore, essentially a creation of capacity in these new sectors (of Industry, Transport etc.) and some prolonged strains in learning to use capacity to the full as it emerges. This goes for non-export agriculture as well where capacity may be asid to exist in the form of already opened up lands). Today, without commensurate production from the new sectors G.D.P. increase is of the order of nearly 4 per cent. Considering the present sectoral relationships and what are the future fast sectors of growth, one could envisage by 1980—perhaps even before this year—a growth rate of 7-8 per cent. Allowing for a time lapse in developing thrust, if we made the assumption that the higher growth rate of 7-8 per cent began to operate by about 1970, then we would have a position where G.D.P. is about Rs. 9,000 million in 1970 (at a 4 per cent rate of growth) with a faster spurt up to 1980 by which time we should be running a G.D.P. rate of something like Rs. 17,000 million or nearly 3 times current national income, against a total population in that year which is less than double the present*.

*This is not too rash a picture because on the assumption of gross savings of 14 per cent or something like the present rate, the capital output ratio would have to shift from about the current 3 :1 proportion to 2 :1 to give the requisite rate of growth. In fact, the gross savings figure over time is bound to be even greater and the capital output ratio need not even come down as much.

I wish to pause here a few moments to consider the adequacy of the theoretical pattern of development that we have adopted in practice. As I said earlier, the approach is one broadly of import substitution and creating of capacity to achieve this by organising capital resources internally and externally. This is akin in several respects to the Harrod-Domar thesis on the economics of dynamic growth wherein capital is considered the prime engine of growth. Savings which theoretically might reduce demand and therefore employment, are used as capital and thus become available to maintain employment as well as to create new capital for growth in a subsequent period. This concept is considered satisfactory in a closed economy (that is one not relying on the outside world), but it has been argued that in the real world such an approach immediately leads either to inflation or balance of payments crises. It is suggested that by exploiting technological change (combined with natural advantages) it would be feasible to develop significant export lines which alone can solve the crises that this development process would otherwise face. It is this growth, so the argument runs, that creates capital and not capital that createy growth. This is briefly what the school of thought represented be Abromowitch—Solow would argue. These names, incidently, are mentioned though pertinently, also to remind that in the body of economic doctrine if one does search adequately one may always find an antithesis for a thesis, that in this world of economic dialectics there is for every Harrod an Abromowitch and for every Domar a Solow! There is no need thus to accept either argument at face value.

What however, would the trend for 1980 look like in terms of such a controversy! Thinking in this country has accepted that new export lines must certainly arise in the future, although development so far does not indicate trends in this direction. There is, of course, a real problem in that the present pattern of development clearly entails a period of imports not only of machinery, equipment and some skills, but also of considerable working cpital in the form of materials, other intermediate goods and components. This is the problem of what is now described as Maintenance Imports (on which the Second Indian Five-Year Plan floundered). It is difficult to see that take off could be initiated nowadays on the basis of export lines. Technology and natural factors are not very helpful, apart from the scope for stepping up further the already existing large export sector. In the old days countries could take off by export-oriented development, using natural, technical and political advantages, and thereby use the capital surplus to create capacity in other domestic sectors like food, light industry, transport and the like. Today, countries must take off largely by investment for domestic production —and wait, till this capacity is built up, and till we learn (the faster the better) to use this capacity fully. It is certainly a strain on prices and foreign exchange. It could be partly offset if the work force were large enough to knock for employment opportunities at given wages (as happened in recent years in Germany and Italy) and if invisible foreign incomes (like Italian tourist earnings or foreign aid for developing countries) are available in adequate quantities.

Viewed this way, the more efficiently a pattern of development based on consumer or wage goods is planned and co-ordinated in execution, the shorter the waiting period before significant growth in G.D.P. begins to show itself. There is, in other works, a case not for a dilution in this approach; but for strengthening of the approach. This is not to say that new export lines will not be developed. But perhaps these will arise out of the first stage of growth and out of its surpluses and experience. Both inherently in the situation, and in the context of world trends in intra-regional co-operation, one may see by the next decade the existence of a number of new export earners made up of a variety of miscellaneous proceessed items covering natural products like nuts and canned fruits on the one hand and some large lines like tyres and tubes on the other. It is difficult to specify particular items as such in regard to their future, but it seems fairly clear that with increasing awareness of our own resources in their raw form, with increased technical ability and confidence in using them, and given the current thinking regarding trade as between nations and regions, a respectable contribution to export incomes would be made by new sectors in the anticipated growth rate of 7-8 per cent of the future that I mentioned earlier.

III

I now turn to slightly different problems of prognostication. These are to do with money itself which, as you know, is considered the means of financing development. Genuine doubts have been cast as to the availability of money resources to finance investment given certain current socio-financial policy commitments, which themselves are in addition said to create inflationary and foreign exchange problems for investment and growth.

It is much less known than should be that today a little less than half the total budgeted expenditure (and quite half budgeted current expenditure) takes the form in one way or another of subsidy payments. We are wont to think only of the rice subsidy, without realising that other crops, as well as items such as the Railway and C.T.B. are also in receipt of subsidy payments. A further element is the free health and education services whose payment costs raise questions of alternative choice in the use of funds vis-a-vis investment in, for example, industries or fisheries. It is also little realised that our irrigation schemes, taking all the aspects of land clearing, land development and land settlement, contain to the extent of $\frac{1}{3}$ of total costs, a social service element which is not economic investment expenditure. Now, to point these out is not to condemn them. On the contrary, we have today adequate theories based particularly on the view that investment in healthy, educated and therefore capable human beings (which has been called investment in human capital) is sound economic development policy. There are abundant statistics now to suggest beyond doubt that growth in advanced countries, including Germany, France and now Italy, which staged their post-war economic miracles, was helped and made possible in a big way by this built-up availability of the stock of human capital. The mistake that one has to avoid in things of this nature is, however, to take up ideas found to work elsewhere and to transfer them crudly to a different context. In a different historical stage of development, such as we are in, we could easily run into dangers of over-emphasis in matters of this nature. I think a little thought will make it clear that what is required is to know the right proportions in which, at a given time, to spend on social welfare and direct investment respectively, and within the field of social welfare and human capital investment, to know which aspects of it are more relevant in our present phase and which less so. We can come to this later. What I might comment on just now bears directly on the issue of our present total subsidies, particularly the rice subsidy which is now not only the means of cheap food for the masses but almost the source of two schools of economic thought! Yet, I am not evaluating here its role as an instrument of food production, as a check on the rising cost of living for the masses, or as a means of containing wage levels and industrial costs. My aim is to see what is more of interest in terms of 1980, namely whether the money cost, whatever the merits or otherwise of rice subsidy, could be carried into that period—and whether in fact it would be so carried. Rice subsidy is of course the largest single subsidy element in our public financing structure. Of the others, some such as those on transport and irrigation, may get wiped out for one good reason or another before long. As I said earlier, we are increasingly learning to use capacity more efficiently and one could envisage economic operations in spheres such as transport. This would by itself reduce the total subsidy amounts. But one could see

steady increases in education and health, even if some practical schemes of cost bearing by citizens (on means tests or other bases) are introduced. Even if we assume (not quite accurately yet justifiably for the present argument) that the net future effect of subsidies other than rice would be either steady or only slightly upwards, we are left with the cost implications of rice as far as budgets of the future are concerned.

One, not very proud but alleviating factor today is that the physical capacity of the public sector to spend on capital investment is still limited, as evidenced by the under-expenditure figures year after year on the budget's capital account. Now, this certainly justifies the argument that there is no need to disturb the subsidy pattern for the sake of development, because quite clearly development cannot take in more funds. The fact that development itself is financed entirely from the deficit side of the budget is not necessarily wrong or bad. Any judgement would depend at least on the total investment pattern for which this finance is used, and the pattern of subsidy and its effect on productive efficiency and industrial peace, apart from other factors. In fact, the policy of the current budget, of absorbing additional purchasing power created by deficit budgeting, by deliberately letting in imported luxury goods into the market at peak prices and by taxes on non-essentials, combines soundly with the pattern of cheap food and cheap textiles. To go back to the main point, however, one must say that it is no advantage, economically, socially or politically, to have to confess that development cannot take in more funds. There is little doubt, therefore, that development will increasingly take in more and more investment in the coming years. As for me, this expectation is almost a premise since I have already posited rapid growth in a few years time.

Now, how will the rice subsidy look at that time. Some relevant figures are perhaps the best way of finding this out. First, an estimate of projected Government revenue. On the basis of alternativel computations (made partly for purposes of cross-checking), it appears that Government's current revenue which was,

> Rs. 1,600 million in 1962 would on the present rate of growth of G.D.P., be in the region of Rs. 2,900 million by 1980. On the Plan rate of growth which is 6 per cent, the anticipated revenue in 1980 is not less than Rs. 4,900 million.

Next for the anticipated subsidy burden. It is anticipated on the basis of 10 per cent of production being retained by producers for consumption and seed paddy, and the present G.P.S. price, that 32,948 cwt. of rice would pass through the G.P.S. in 1980, involving a producer subsidy of Rs. 652 million.

The corresponding consumer subsidy on the basis of current prices is expected to be Rs. 334 million, making a total rice subsidy of Rs. 986 million by 1980.

There is another food subsidy element on onions etc., which is small and which may be anticipated at the level of Rs. 10 million in 1980,

making a total gross subsidy of Rs. 996 million by 1980.

The net subsidy, however, would be less profits on sugar and flour. Again, going on reasonable assumptions, it is anticipated that these profits would amount to a little over Rs. 316 million. The net food subsidy that is anticipated in 1980 would, therefore, be Rs. 996 million—316 million=Rs. 680 million.

What would the implications of this look like for the future of our economy. The net subsidy which was Rs. 230 million in 1961-62 would have about trebled by 1980. As for Government's revenue, the position would depend on what our growth performance is going to be. On the present rate of growth of 3.4 per cent, the figures that I have given earlier show an increase in 1980 which is less than twice the revenue figure for 1961-62. On this basis it is clear that the two rates of growth of subsidy and government revenue, show clear disparity to the disadvantage of the latter. On this trend subsidy would, like the proverbial camel, take up the entire income in time. If this is not due to occur by 1980, it would on the basis of these figures still throttle investment needs in a phase when they would be strongest and capable of being absorbed as never before. But there is an alternative assumption of Government revenue which I gave out earlier, based on a 6 per cent growth rate. This would mean that Government current income by 1980 would be easily three times its income in 1961-62. On this basis, all that the subsidy growth rate means is that it would maintain the same relationship to total budget expenditures that it has now—and no more. One is not sure, therefore, that some of the agruments one hears at present about the potential dangers of the subsidy are entirely valid. If the subsidy does play a crucial socio-economic role, then the point for attention in a big way now is rather the policies and measures that must be taken in a physical sense to speed up utilisation of capacity, to step up output and in the overall to expedite the realisation of a faster rate of growth than we have now, with the aim in a few years of attaining at least a 6 per cent growth rate posited as our goal. This objective, as I have mentioned earlier, in a broad review of possibilities, is not beyond realisation. In these circumstances one thinks that the role of the subsidy should, in the interests of future financing itself, be evaluated in a narrower context, namely as to how useful it is as a production agent for paddy and as an economic tool in controlling wage structures and costs.

Before passing on, a word may be said about sugar. Despite present price fluctuations, the nature of the productive mechanism in the world sugar industry justifies the expectation of a clear trend that is easy as far as prices go, so that future budgets too could slice off fair margins by maintaining high domestic sugar prices. Against these fiscal hopes, however, we have the dilemma of our own development plans and targets for sugar production in this country. The more sugar we produce in our present circumstances, the more unfortunate it threatens to become for the public financing of our subsidies. My prognostications say that by 1980 we would easily be self-sufficient in sugar! It is in fact the same in rice, where the more we produce locally, and the more population we have, the more burdensome it becomes for the budget through the producer and consumer subsidies. The only let up on this pressure so to say, would be if sugar were produced by us as well at world prices. Perhaps we may be doing this by 1980. In the meantime, the interim period may create problems along with problems created by the slow growth rate of the present.

One does not think that the answer need or should necessarily lie in the abandonment of the subsidy policy. The producer subsidy performs a production function which will, one thinks, be rightly continued. In fact, with gradual all round increase in costs down the years, the present guaranteed price of rice may just represent in time a fair level of true costs and no more. In other words, it would not by that time be any more an aberration in the general cost structure that it perhaps is now. The only problem left would be to bring these costs—all costs in the country—in line with international costs by an appropriate devaluation, which I think at that date, when the take off phase is over, would be an advantage to the economy. One cannot say the same, however, about the consumer subsidy, at least at its present level. Given the future population increase, rise in subsidy quanta, the levels of other costs in the economy, and not least of per capita incomes generally, one can see if not an abolition, at least a considerable upward revision in the consumer price of rice. I would not dare to say more.

I mentioned once earlier that it is easier to look at 1980 than say 1970. On this particular point of subsidy, critical problems also seem to be less in 1980 than in the intervening phase that has to be traversed. While in the long term of, say 18-20 years from now, our growth, price rises and income rises would enable the position of a rice subsidy scheme to be placed in context, in the immediate years before us a number of problems confront, to which it is difficult to give a clear answer. The economy's growth rate would not be anything like 7-8 per cent. And so, the rise in budget incomes would not perhaps be at the same pace as the rise in subsidy burden.

In addition, increasing internal sugar production would also be running at high costs. An inevitable contradiction would arise in this mid-stream phase for which no tools or financial equipment would perhaps be available for repair, especially with absorptive capacity of investment rising rapidly. One is tempted to compare onself to the astronomical parallel of forecasting an immediate critical phase of a sub-period, with a promise that the major period thereafter would see prosperity in the ascendant and a rapid rise! Fortunately, I have not undertaken to predict what would happen in this intermediate phase, since I have fixed my eyes on 1980! One cannot help, however, viewing the next few years on this aspect of our problems, with considerable misgiving. If we survive this crisis we will live in 1980 with subsidies in slightly adjusted form; if, however, the crisis and the transition breaks the back of our financial structure, then by 1980 we may be having a system with only consumer subsidy whether directly as now, or indirectly by subsidising the farm down to market rates as is the current U.K. practice. Either way, I think the low cost pull of the consumer and the farmer's role as a force will see some financing scheme involving exchequer funds, for it is part of experience that development does not easily remove food problems from an economy, whether the problems are those of producing food or of consuming food.

IV

A reference I think is now called for to the other major financial problem, namely the budget deficit and its concomitant, the threat of inflation. By inflation I do not refer to a known steady trend of rise in prices, but a rate of rise that becomes unmanageable and upsets drastically not merely price relationships but also the established liquidity preference in the economy, particularly as between money assets and physical assets. It is necessary to distinguish here between two types of pressure on prices. When an investment is made by borrowing money from a person, the money so spent is not an increment to total money supply, but only a change of the agency through which and the object for which the money is spent. Deficit financing through the budget by floating loans that are subscribed by savers is of this type. Now, there is a pressure on prices because the money is spent on purchases, on wage payments, and so on. This pressure, broadly speaking, will exist till the investment itself starts producing the goods that it was meant to produce and in the quantities it is capable of producing. Thereafter it would be matched by goods and the price pressure will cease to operate. What is vital in this process from the view point of prices is that this time lag, between investment and full production, should be as brief as possible. It is also important, of course, that the pattern of industries on

which the various sums are invested is such that there is no lop-sidedness and that the whole of output will be bought up. The second type of price pressure arises where the budget covers deficits by borrowing money not from savers, but from banks which 'create' money (including the Central Bank). This is new purchasing power and is an increment to total money supply. To the extent that this increment is greater than such increases as are normally effected in any economy to keep pace with increasing demand for money in transactions, to that extent there is an increment to money supply which is unrequited and which, therefore, introduces the beginnings of pure inflation. It must be remembered that so long as there is bank borrowing of this nature, the inflationary component can be even the whole of such borrowing if we also remember that the increased transactions demand for money supply is met in large measure by the velocity of money for the number of times the rupee will do the work of effecting transactions. As we know, a rupee note does not perform only one transaction for its owner but continues to serve similar functions for its subsequent recipients in a given period. With the increase of the cheque habit, this velocity factor would assume more pronounced importance. On the other hand, in the past and even in the present in some way, several areas of the country have been innocent of cash as a means of effecting transactions. To this extent the pressure described just now would be less. Personally speaking, I doubt if we can consider this a significant absodent of price pressure today. In any event it could not be so considered in later years.

Most of this is realised by people who practice the subject. Still, one is led to doubt—judging at least from the controversies—whether sufficient clarity of expression has been brought to bear in highlighting the phenomenon of imbalance or crisis and in recommending the specifics for their solution. There is no doubt that we have had *inflationary* financing, in the sense I have described, in the last few years. But one could not say, therefore, that development should not be financed by *deficit* financing. I am assuming this in future years as well. One suspects that there has been a tendency to raise one's hands at deficit financing and thereby not only confuse the issues but also fail to pinpoint that aspect of deficit financing on which warning is necessary. One could of course assert, and should assert, that not even development should be financed by inflationary deficit financing. The volume of inflationary deficit financing of recent years is, admittedly, less than the volume of total deficit financing. Indications are that the former has been of the order of about Rs. 200 million per year on an average in recent times.

Now for the concomitant problem of actual extent of inflation. The whole process in recent thinking on this point has been in terms of runaway inflation—either that this is round the corner, or that this term is all just so much nonsense. Let us try to take a look at the common background of facts. If we assume an inflationary financing rate of about Rs. 200 million per annum, this has to show itself either in a price rise or has to result in drawing on foreign reserves. If we also assume that in the years before import control private savings did not substantially come out in industrial and allied investment and force a demand for imported machinery and materials—indeed all these are fair assumptions—our foreign reserves would have fallen roughly in proportion to the extent of new demand created in the inflationary financing, and would have continued to fall but for import control. Some of the new demands would have been on local supplies and services and exetred some pressure on prices while easing the call on foreign reserves. But this we shall leave aside for the moment. The point, in the historical situation, was that foreign reserves started falling as unremittingly as inflationary finance was being created and bore a fair correlation to the amount of the latter. And so, in a period of 6 or 7 years, our holdings abroad fell to rock botton. This danger, I believe, was pointed out by some before the event; and it materialised. With the draconian measures of control on imports beginning towards the end of 1960 and the start of 1961, attention came to be diverted on the threat of potential inflation as the next outlet for the money pressure built up through inflationary deficit financing. One finds it difficult to escape the conclusion that the rapidity with which a crisis came about in the balance of payments was unconsciously or otherwise projected to the domestic situation, with the result that fears of inflation round the corner, fears of a crisis in finance and the call for drastic re-thinking on financing development and subsidies came to be expressed with considerable urgency and acceptance. What was missed I think was that when our foreign reserves fell by Rs. 200 million per year, this fall represented some 12 per cent of total reserves, while the same deficit exerted inflationary pressure after import control on a Gross National Expenditure figure of Rs. 6,000 million in 1962. In other words, the internal arithmeticas relationship was only something like 3 per cent of total national money expenditures. True, loss of confidence, change in velocity, disgorging of hoardings (even if offset by some monetizing of non-cash sectors) could create runaway inflationary problems almost without notice. But these were the problems, not of the actual situation, but of a different worse situation which unless psychologically whipped up would take long to come up. The basic point missed in the thinking, as one sees it, is that ill-effects were anticipated enormously earlier than at all possible. Now, as I have said, inflationary deficit financing is not for this reason or any other

reason to be recommended. But the manner in which a crisis situation was presented, placed beyond reach opportunities of focussing attention on the real problems inherent in the particular financial policy—namely the emerging cost structure in the new and developing sectors of the eocnomy, the administrative and other pressures of import control, and of course the much more distant inability to meet a steadily built up inflationary problem—if the present rate of growth for some reason failed to quicken. If one can exclude price rises caused by administrative inefficiencies and by policies that are non-monetary in origin (there are such examples today) one may expect general price levels to be something like 50 per cent above the present levels when we approach 1980. Gross National Product which I said earlier would be about three times the present by that date, would in money terms be of course proportionately higher than this three-fold physical increase represents.

It would naturally be a good thing for the future cost structure and competitiveness to develop now without resort to inflationary finance of the type that has occurred. To do this, perhaps one of the things to be attacked would be the subsidies. Yet, not to do so is not necessarily as disastous right now or in the very long term as may be thought. It may be seen from all that has so far been said that a fairly foreseeable growth pattern and growth rate as well as a discernible pattern of financing and cost sturctures can be visualised from where we are today. I have mentioned also that despite apparent despair about present deficiencies of one kind or another in the growth effort several identifiable trends show the development of sufficient thrust to ensure a good future rate of growth. It would be appropirate at this stage, as part of an exercise in prediction, to isolate certain areas of current thought and implementation which presently are hardly perceptible but have inevitably to emerge strongly in the coming years among the major instruments of rapid development. Development thinking, as expressed in practice at least, is so far predominantly in terms of finding finance, whether local or foreign, and using it by 'reacting', if I may say so, to the existing physical environment rather than by planning positive steps. One could say, for instance, that the investment pattern and output pattern so far have largely been ' slogan oriented '—such as growing all our food, stopping imports and making them ourselves, raising cries against losses or waste after they have emerged, and so on. Now, these are not bad or undesirable in themselves. But I think what will ensure the anticipated future growth are those ideas directed towards comprehensive resource assessments, constant applied research and pre-planning, proper techniques of appraisal of projects and programmes, and efficient managerial practices in production, marketing, costing and incentive creation. I think in the future we will see much activity in the shape of all-island resource surveys, a number of techno-economic groups (functioning over a range of industrial categories), a continuing service of sound applied techno-economic studies and industrial plans, and over the general field of other projects, a system of work studies and advance cost control methods —all aimed at the objective of getting Value For Money. This process would render, among other things, the availability of things such as a Textile Plan, an Oil Plan, a Sugar Plan plus a pattern of linked industries on the one hand and on the other, in the field of public works and the like, a system of standard patterns and unit costs, both of which to gether would enable meaningful investment measures and effective steps in implementation. Indeed, if this does not happen, the expected rapid growth just will not occur. I believe that as a matter of compulsion by circumstances, these patterns will operate in the future, whether in the field of Industry or in Transport and Construction; and whether the sector is public or private.

In Finance itself, we would I expect have by then moved towards a realistic system of Programme and Performance Budgeting which, in one sense, is the equivalent of marginal efficiency techniques in industrial operations and which by focussing attention on physical performance and on homogeneous physical programmes would render more feasible the managerial and control tasks which Governments today have to accept as being one of their key functions, We would also, I am sure, have advanced to a stage of having more sophisticated Foreign Exchange Budgeting of a type that really seeks to anticipate the innumerable factors impinging on foreign exchange earning and spending as a result of economic development.

Two other major levers of growth would also have emerged by then. One, referred to in another context earlier, would be the emergence of certain new export lines, including may I suggest Tourism, which would play in some way the role of Leading Sectors in rapid growth—providing in this sense a meeting point for the protagonists of the balanced and unbalanced theories of development! The other line, also mentioned before in another connection, would be a strong pattern of technical education, technical training and skills building as the major instruments of human capital formation which at present has severely restricted the absorptive capacity of investment capital, particularly in maximising production. Here I am thinking not merely of large industries but of a vast range of small-scale production in mechanical and electrical engineering and in the processing fields.

V

Perhaps, all this will account for future rapid development. It has come to be observed increasingly of late, however, partly by inference from experience of countries that have fairly adequate planning and implementation methods, that plans based on production targets in major fields still leave untouched most areas of a country, and throw up the contradiction of continuing depressed areas and depressed people within national boundaries amidst centres of rapid investment and production. These, in fact, have been thought to set potential limits to growth of the developing pockets themselves in the country, based especially on the point that the absence of purchasing power in the depressed sections exhausts the market capacity of new industries or enclaves. Even if these limits are still not within sight in an economy, say India or Ceylon, one could foresee possible defeat for rapid growth in the not too distant future. In fact, the present slow growth rate in India has been ascribed to absence of organised growth in these depressed areas. So, even if we say, for instance, that the Steel industry is expanding rapidly and its limits in market terms are still not reached, the gross growth rate of the whole economy is only the contribution of this industry (and such like) with the rest of the area only helping to pull down this average rate of growth. If the particular growing areas are vast enough and diversified enough, one could say that growth may go on without limit, even though they would not touch the other areas beneficially. In other words, the rich areas within a national boundary may grow richer and the poor areas at least remain poor. The example of the American South has been quoted and the fact has been cited, that it was not till the thirties of this century that development got on in that segment of the American sub-continent. What ultimately created development there, it was shown, was not cheap labour as sometimes augued, but the creation of a market. In other words, the means to development was development itself! The method by which this initial development, or the market, was created is the core of the policy instrument implied in the thinking I have just outlined. I feel almost sure that we may discard this thinking only at risk to ourselves.

Very recently this problem has yielded at least two known theoretical formulations. Galbraith, I believe on his Indian experience suggested what he termed the 'mass consumption criterion'[1] as a basic distinguishing yardstick by which to evaluate investment priorities and thus to formulate plans. This meant that investment plans should be guided by the types and scale of projected demand for commodities that are consumed by the mass. This being equivalent to the low income and wage earning groups, the commodities would be the range of items that are consumed by people at such income levels. I believe the implication was clearly not that capital goods like steel should not be in the plan, but that the starting point in making the projections of future demand as well as the desired scale of output required in Steel and Coal and what not should be the scale of demand for items consumed by the low income mass. This, as a thought, has close affinity to the description of 'Wage goods industries as basic industries' which I happened to espouse in certain earlier publication.[2] In addition to the technical qualities of complementarity and cumulativeness, there were also implied in this approach the ideas of shorter gestation periods in realising investment and output, and of quicker and more widespread strengthening of purchasing power than may otherwise be the case.

I am not sure that Galbraith himself in enunciating this theory thought so much of the problem of depressed areas and sections of peoples in the form in which I described these earlier, namely as failure to spread growth and income benfits to all areas of a country. But certainly he had in mind the problem of an inadequate growth rate.

The second recent formulation that has come to notice is from Mr. Rostov of 'take off' fame. To describe what he has in mind, he has now expanded his own vocabulary by using the term 'nationalisation of the take off'[3]! Starting from the premise that take off at limited focal points does not spread and that as a result the growth rate too tends to stick, he sees a basic need to spread income creating activities over all areas of the country. This would not only raise incomes in depressed sections, but would be the instrument for widening growth horizons for the whole economy and thus lead to faster growth of incomes, demand, output and further incomes.

1. As reported in Indian journals.

2. Vide my 'Ceylon Beveridge and Briton Woods' (Col. 1946) and 'Economics of Full Employment in Agricultural Countries' (Col. 1956).

3. Vide Eastern Economist, April 12, 1963. Subsequent articles by him have also appeared elsewhere in the same vein.

Now, it is not necessary to view this approach as one of regional balance, although the latter has its own importance. But as a pointer to the need for building up incomes and demand power over the whole area of a country's work force and population, I doubt if its importance in the rate of growth problem can really be discounted. I would wish to add certain clarifications of my own at this point. Modern developing countries have some specific peculiarities in development which the countries that were developing in the last century did not have. One of them is that when industries started for the first time in the world, they were by today's standards if not those of that period, medium or small size ventures. Their technologies, on looking back, were sufficiently primitive to give scope to a number of dispersed industries and to a number of small-scale industries in various lines. Output and income were generated, despite leading lines like coal and iron, over a wide area, and technical skill (which incidentally is a key factor in future growth) was being built up over a wide area. These were also assisted by the fact that in those days markets by conquest enabled the outputs of industrial production more easily to exceed the limits of home consumption. More often than not today, industries are of the latest pattern technologically (at least if we exclude automation) and of considerable size. This would be so even where they are smaller vis-a-vis another developing country.

For example, a 100,000 ton cement factory here would be small compared to a 1 million ton unit in India. But it would not be small in relation to the size of the particular country and its market. The result is, especially in the relative absence of export lines, that a few units in each industry can dispose of needs, leaving in turn vast sections of the country and population for long periods at least relying fully or partially for economic occupation, simply on archaic modes of production. The fact of technological backwardness, manifested especially as lack of construction and production skills, slows down even the setting up of the limited number of units required to satisfy the home market; and in the meanwhile smaller scale investments would not be set up on the ground that they are less economic than large scale, even though it may mean dispersing more widely the income and other benefits of investment. The spread or dispersal of skill building, or production, or of earning power has to be quickly and simultaneously provided if the development process is to have adequate impact on the growth rate. Historically what occurred was that a prosperous agriculture and animal husbandry and a number of processing industries drawing on domestic or colonial agricultural production for their working capital, or linked to large industry or using industrial by-product materials, continually developed alongside the classic industrial revolution. In today's developing countries, the emerging factories are more isolate and have little counterpart in the rural sector, which remains backward and almost unchanging. The changes that observers have noted in a rural area where successful small industrial units do come up and where both these and large units together stimulate production of agricultural raw materials, are some evidence of the contribution that this process could make, both by itself and by inter-action with other sectors, to a faster rate of growth. The demand limits of a new sugar or textile factory, for instance, are clearly restricted if the sugar cane or the cotton were not grown and sold to industry by local labour and if, thus, the country was poorer in total demand capacity to purchase industrial output. The same would go for small industrial units in an income and demand sense, whether such units useby-products of major industry or make components of these industries in various parts of a country.

What created a somewhat better impression in Ceylon may have been the employment and income scope provided for several years now by land colonisation, by the Guaranteed Price Scheme which boosted incomes that would otherwise have come only by modernisation, and in a limited way by the small industries represented in the uneconomic handloom. In point of fact, however, as national income figures show, these have been insufficient to ensure rapid enough growth. There can be little doubt that the sooner all sections of a population enter into new and modernised economic activities (of various scales of output) so much sooner would rapid growth be brought about.

Now, it is not suggested that this should be brought about by opting for non-economic smaller units in preference to larger scale optimum units of industry. But the historical Income function of dispersed development has to be created by action which it was not necessary for the older industrialised countries consciously to foster in their time. This calls for special priority for an area of work which in an earlier century was part of the growth phenomenon itself. A textile factory or a cement factory should be as efficient as it can be in the country and, therefore, relatively large. Indeed, past policy on textiles had a lot that was wrong in it. It would be a mistake, however, to presume that there are no other ways of introducing rural industry. Even in the handloom the present policy shift to art lines is a right step. So also a possible modernisation in brick manufacture. Besides, there are other approaches. Smaller industries based on local materials, whether they are nuts like cashew, or various types of fruits, or minerals like graphite; industries of a servicing nature such as units to repair small machinery and equipment; industries using products or by-products of large industries of which exercise books and envelope making are an existing illustration; industries making components for larger industries such as the making of nuts and bolts and wheel rims—all these, taken together with more efficiency in agriculture and animal husbandry and with extended raw material producing

programmes as a result of industrial development generally, provide a sure basis for a nationalisation of 'take off'. There is just now in this country a trend having some relationship to this but based entirely in and around Colombo. Import bans have created a number of small units in various stages of component substitution. In idea, however, this has little in common with the countrywide programme that is implied in the spreading of take off. In the long run, the latter programme has to be strongly based on local resource surveys, feasibility studies and countrywide investments based on these—and not on importing components, assembling them here and naming the process either import substitution or small industry development in the national sense. Such an idea includes, however, the organising of industrial investors in special locations, of which the Industrial Estate idea is one of the best expression.

We need to be cautioned also on another interpretation of this idea of national development. This is the idea described in this country as rural development and in India as community development. One does not, I am sure, nationalise take off by pious intentioned welfare organisation, whether statutory or voluntary, to build roads, cultural centres, free buildings of varying sorts and the like, to salve in the result rather a social conscience than to fulfil an economic objective. It is not only that what rural development can do is being poorly done. The fact is that the totality of rural development in a real sense implies work being done by several more agencies in the rural area than the rural development organisation alone. Were they looked at together, and their existing programmes of work, whatever they be, put together, and a co-ordinated programme exercise done, one would immediately see that rural development in effect involves complete planning and programming in all fields of irrigation, agriculture, credit, marketing, small and medium industry, power, transport, education, health and other services. It is not a social service programme for health and sanitation, a little education, some water and roads, and maintenance of a few ponds. It would appear that the Indian community development programmes, which have counted wide outside acclaim, have been roundly criticised at home as failures. They have yet to reach out to this level of practice that I have mentioned in regard to the real problem of the rural sector and their role in the broader context of the country's development.

This medium scale field is one of our most retarded sectors at present. But I believe equally clearly that events (shall I say development contradictions arising when we pursue the dichotomy of a large industries sector on the one side and a mere paddy and rural social service sector on the other) will push the new development into prominence—in a manner that at least by the next decade should contribute strongly to the high growth rate that that I have been speaking about.

Such a trend, however, will not emerge unless the country's planning and organisational machinery for development is conceptually adequate to serve as the effective vehicle of new activity that it should be. This machinery we do not have at present. Theoretically, one may list the organisational aspects of development as consisting of Planning, Programming, Implementation, Supervision and Control or evaluation. It is fair to say that these exist today in any degree at all only at the central points of the Government and the administration, and certainly not in the periphery. To use terminology that I have found convenient, there is 'vertical' planning machinery of sorts here today, but little or no 'horizontal' planning machinery. One should not expect the development anticipated in the rural sector unless there can be effective accepted machinery for horizontal planning purposes. We have had, off and on, a lot of talk about co-ordination in the rural sphere, but action, especially right action, has fallen far short of verbal achievements. The total nature of the rural problem and the need for all organisations (as opposed to some alone) to be co-ordinated, the need to centre authority in this co-ordination at appropriate focal points, the need to allocate spheres of authority to the various component units making up this co-ordinated machinery, the need also to allocate authority at different tiers up to the district organisational level—all these await further understanding and mental absorption before horizontal planning can emerge successfully. Decentralisation in planning, one may emphasise, is not just a split-up of National totals. It is effort from below aimed at discovering and co-ordinating and implementing programmes that would otherwise have largely gone by default. Once this does happen, however, other matters such as the planning mechanism, preparation of programmes, the role of the Centre and so on, would fall into place. I am sure we are now at a point when we need no longer consider this idea as being before its time. If I may be permitted a relevant digression, I did have the experience of attempting something of this sort in an official capacity in one district about 15 years back, only to find that I was a decade and a half before time! Strangely, the reason was not lack of local popular enthusiasm or even the ability to do the things necessary, but official obduracy at other points in the district, helped of course by the fact that Government itself at that time was innocent of planning or co-ordination in a meaningful sense. I do not think, however, that it is necessary for me now to depart from the predictive and indicative orientation of my discussion and to be imperative in my prescriptions. I think there are adequate indications that rural development co-ordination in its proper sense will begin in the near future. It is indeed difficult to say whether it would have set in, particularly in a fully operative form, in say three or five years from now. Here, one would wish to be a little impertative! But looking into 1980—which is my safe refuge!—I have little doubt about the inevitability of this development.

VI

I shall conclude by reference to an intangible, for failure to do so could rightly be considered a lapse. I refer to the factor of human relations, of the sociological and psychological forces that need to be recognised in order to achieve the rapid increase in national output. I should straightaway state that it is a matter which in its detailed aspects I would much rather leave to groups that are so amply labelled under categories such as sociologists, social psychologists, and social anthropologists. I only desire to venture the belief that development produces its own solutions. Of course, even in this sphere of human relations, pre-planning can hasten the right solutions. One cannot, however, wait for solutions and in this context it is relieving to hold a view that the development forces by their own pressures and challenges, lead to responses and adjustments that do turn our right. After all, the educational forum is not only the classroom but the innumerable institutions of the outside world. Indeed, education in vacuo is virtually impossible to impart, requiring the inherent presence of the external environment and the essentially educational process of ecological adjustment. What is going on within industry here today, in the agricultural efforts, in public consciousness about other spheres, in Ministry approaches to planning or Government approaches to budgeting and the like, is already making towards these changes. I venture to think in the field of country participation in planning and implementation of development programmes, that the machinery for rural areas, or horizontal planning, which would emerge will be a great contributing factor to popular education and participation. Some of the instruments which sociologists would probably acclaim—such as a basis for evoking creative interest, for co-partnership between sections of rural people, for placing a discount on window dressing, and for adjustment to the new and different behaviour patterns or codes of modern productive organisation while using some of the inherited group values of the past—these I think will emerge at least much more easily than now with the type of rural planning machinery referred to.

In much of what I have tried to say, couched in the language of future trends, it might have been possible to discern what are in effect the outlines of current shortcomings. They are a statement of the things that have now to be done to achieve rapid growth. But the predictive cloak that I have woven is also I believe valid, for the reason that events in their various streams, and people's judgements and responses in relation to these, would generally be in these right directions. Frustration with the present, that is with its shortcomings and its excesses of thought and action, is as natural as the shortcomings themselves; so is the pessimism at times about the future. Growth is in fact slow and a lot of things should have taken place which could have imparted more drive— at what social or perhaps economic cost I do not guess for the moment. Yet, it would seem fair to apply the generalisation in our case, too, that once a society has purpose, expressed in terms of broad objectives, it has, save rarely and appearances notwithstanding, the ability to achieve it without knotting itself up to the point of immobility and without rendering itself so unstable as ultimately to destroy its own integrity. At times, this sense of purpose may appear to show itself in forms that seem uncontrolled. True, as Galbraith so well states "Every Society must be protected from a too facile flow of thought. In the field of social comment a great stream of intellectual novelties, if all were taken seriously, would be disastrous. Men would be swayed to this action or that, economic and political life would be erratic and rudderless. In the Communist countries, stability of ideas and social purpose is achieved by formal adherence to an officially proclaimed doctrine. In our Society, a similar stability is enforced far more informally by the conventional wisdom. Ideas need to be tested by their ability . . . . to overcome inertia or resistance". This 'conventional wisdom' if I may paraphrase, incombination with ideas, provides against too rash action, even as it impels the Society concerned towards its declared goals.

I have taken longer than I should have. To have endured me in patience makes me grateful; to have done so on this Subject is a tribute to your own Conventional Wisdom! I thank you.

SECTION A—INVITATION LECTURE

(Wednesday, 20th November, 1963)

EVOLUTION AND THE PROCESSES OF DIFFERENTIATION

by

E.N. Willmer
(University of Cambridge, England)

In a climate like that of Britain, though probably less so in one like that of Ceylon, a major item in an industrial budget is the loss of work through rheumatoid and arthritic diseases and other more or less chronic ailments involving the bones, cartilages, joints and connective tissues of the body. A certain elementary mumbo-jumbo of treatment with salt baths, radio-therapy, massage, and corticosteriods, certainly exists for the alleviation of such complaints but in fact the whole problem is still so wrapt in mystery that witch craft and medicine are about equally helpful. This state of affairs will presumable persist until the connective tissues are taken seriously, and are fully studied at the cellular level, instead of being discarded with the fascia in the anatomy school.

The cells mainly concerned with the connective tissues belong essentially to two major groups: the fibroblasts (mechanocytes) and their derivatives such as the chondroblasts, osteoblasts, form one of these, while the macrophages (amoebocytes) form the other. Unorganised growth in tissue cultures of the connective tissues (including, of course, bone, cartilage, tendon etc) brings these two classes of cells into the open, though probably in somewhat simplified and dedifferentiated forms, so that their different properties and behaviour are then clearly seen. Though a detailed study of these differences is very revealing and of fundamental importance to the study of the connective tissues as a whole, the prupose of this present discussion is different. It will, in preference, be devoted to an attempt to answer such questions as "why are there these two types of cell?" "What purposes are the two types serving in the body?" and "What is the relationship of the one cell to the other?" In essence these questions involve an evolutionary problem. Have there always been mechanocytes and amoebocytes? if not, in what sort of animals did they start?

There are, in fact, very few multicellular animals in which there is not some trace of connective tissue, composed essentially of collagenous fibres in a mucoprotein matrix, and in which both fibroblastic and macrophagic types of cells are present. As an example of a very primitive organism in which there is already a recognizable connective tissue the calcareous sponges may be taken. The researches of Fauré Fremiet (1931) and of Gross Sokal and Rougvie (1956) have clearly demonstrated the presence of both the cell types and of their typical products. Moreover the early work of Minchin (1900) on the embryonic development of the sponge has suggested that the collagen forming cell, the scleroblast (= fibroblast) is dervied from the ciliated cells which constitute one pole of the sponge embryo, while the wandering amoebocyte cells arise from the larger non-flagellate, amoeboid and phagocytic cells of the other pole. Thus, if this embryological derivation is accurate, it means that at least some of the differences between fibroblasts and macrophages are likely to be present in these very primitive epithelioid cells which constitute the blastula stage of the sponge embryo. Thus, a study of the nature of the differences between the flagellate cells and the phagocytic cells in these creatures may be pertinent to the present discussion. This study has yet to be made on the sponge embryos. Perhaps the warmer and more kindly coastal waters of Ceylon may be more suitable for this investigation than the temperate and more temperamental waters lashing the coasts of Britain where the breeding of sponges is only a very seasonal affair. However, there is fortunately another very convenient organism, *Naegleria gruberi*, a soil-inhabiting amoeba, which can in its ordinary every day life be made to oscillate between being a typical creeping amoeba, feeding by the ingestion of bacteria, and a free swimming flagellate organism with two to four well developed and typical flagella.

An investigation of the factors which lead to these changes of form and behaviour reveals the fact that the ionic content of the medium is often the determinant. Many other factors such as osmotic pressure, temperature, O_2 content, and other constituents in the medium may in addition influence the behaviour of the Naegleria, but experiments indicate that it is the ionic content of the medium which ultimately calls the tune. Again, it is probably the cations which are the determining factors, but the negative ions are also of great importance in a variety of ways (Willmer, 1956, 1958). In general, the flagellate form is assumed when the *Naegleria* is in danger of losing salts to its environment and of becoming unduly hydrated. When the external environment is relatively more concentrated than the organism then *Naegleria* assumes the amoeboid form. Interestingly enough another amoeba (*Chaos diffluens*) starts to pioncytose (i.e. absorb droplets of fluid from the environment) when the external concentration of sodium chloride rises above about M/16 which is the concentration at which *Neagleria* changes phase (Chapman-Andresen, 1958). Briefly, then, the observatons on *Naegleria* suggest that this organism is flagellate in response to a dilute medium and amoeboid in response to a medium more concentrated than itself. This in turn suggests that the phase which it adopts is somehow concerned with how the organism maintains its ionic equilibrium in spite of changed environmental conditions.

With these observations in mind let us then return to the sponge embryo as indicative of a state of organisation which may well have occurred in the evolution of higher organisms. The sponge blastula represents a state of organisation which is so generalised and so typical of many invertebrate embryos that it can serve as a useful hypothetical example, quite independently of whether or not sponges as a whole are on the direct line of development of the higher metazoa. Let us therefore suppose that the flagellate cells of the sponge embryo behave towards the external environment like the flagellate *Naegleria*, while the phagocytic cells behave more like *Naegleria* in its amoeboid phase. What effects will this have on the organism as a whole? The blastula is a spherical shell of cells enclosing a fluid-filled cavity. The composition, nature and amount of that fluid are probably of great significance to the organism since every cell is in contact with the contained fluid. The fluid, in fact, is the archetype of the internal environment, le milieu interieur of Claude Bernard, and as such it presumably requires regulation. This point can perhaps be accentuated by illustrating what happens to similar systems under corresponding environmental influences. When tissue cultures are made from small pieces of the cortex of chick kidneys and they are grown in a plasma medium, the tubules which are actually cut tend to reorganise themselves into hollow vesicles. Those which are formed from the proximal tubules then enlarge and become spherical like hollow blastulae, while those from the distal tubules tend to shrink (Chamber and Kempton, 1933). The sponge blastula, apart from its normal slow expansion during growth, neither dialtes nor collapses. Presumably the entry of fluid into it is a strictly regulated procedure, so that the cavity neither overfills like the proximal tube nor shrinks like the distal tube. The cavity is surrounded by a single layer of cells and the fluid presumably enters and leaves through or between those cells in a regulated manner. Neglecting for the moment the effects of the cell membranes adjacent to the lumen and considering only the major ionic activities of the flagellate cells and the amoeboid cells, it is clear that a state of balance could be set up between the activities of the two groups of cells, so that they regulate the ions and water which enter or leave the cavity. Overactivity in one half would tend to be opposed by corresponding counter-action by the other group. In other words, the flagellate cells and the amoeboid cells, by virtue of their opposed activities, could form the primary mechanism for the control of the original and primaeval internal environment.

Later, this primary internal environment became colonised by cells dropping into it from the layer of surrounding cells as it now does in the embryonic development of the calcareous sponge. In the sponge some of the cells which drop inwards from the flagellate and become fibroblasts and produce the collagenous and mucoprotein matrix, while some of the cells which drop in from the amoeboid, cells remain as the amoeboid wandering cells of the connective tissues comparable with the macrophages of higher organisms. While these internal cells can no longer have the primary function of regulating the incoming and outgoing of fluid and ions in and out of the organism as a whole, it is worth emphasising that they are derived from the two original and different stocks of cells and are therefore likely to inherit something of their originally mutually antagonistic properties and to contiune to work symbiotically and synergistically for the good of the whole.

With this view of the archetypes of fibroblast and macrophage in mind then, it is time to return to the connective tissues of higher organisms and man, and to ask whether or not some traces of this primary symbiosis are not still present. Are subtle differences in the ionic content of the animal perhaps responsible for changes in the character and properties of the connective tissues? Vice versa do abnormal connective tissues reflect abnormal ionic and water balance? Are macrophages just passive scavengers in the connective tissues or are they still actively synergistic with the fibroblasts in the maintenance of the connective tissues and their all pervading tissue juices?

Finally, it is pertinent to remark that the adrenal corticoid hormones are very active in determining the type of behaviour of *Naegleria* (Pearson and Willmer, 1963), and it should not therefore be entirely surprising that pathological connective tissues sometimes yield to treatment by corticoids just as they sometimes do when their owners "take the waters" of some expensive spa and presumably alter their fluid and ionic balances. If we knew more about the requirements of fibroblasts and macrophages and more about the nature of the relationship between them, perhaps the medical treatment for arthritic and rheumatoid diseases would finally pass out of the hands of the witch doctor and become more reliable. Prevention might even become possible.

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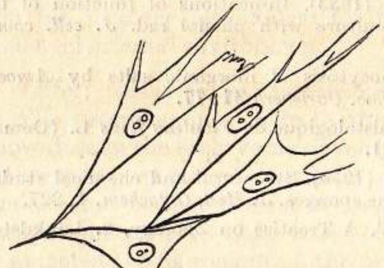

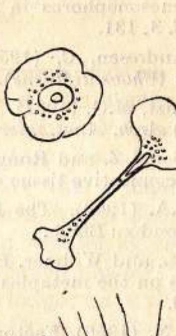

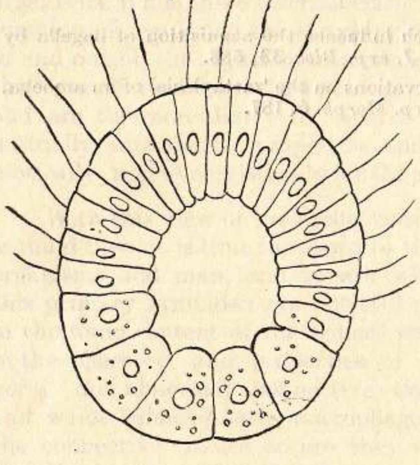

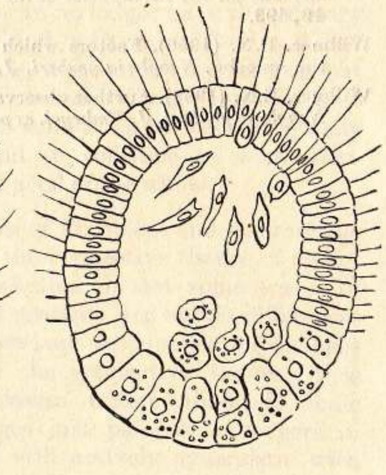

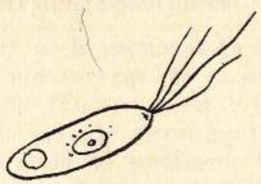

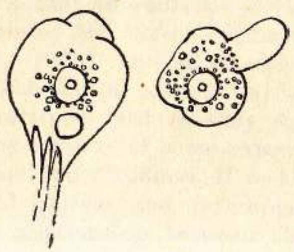

Figures

1. Group of four fibroblasts in tissue-culture.
2. Two macrophages in tissue-culture.
3. Early blastula of calcareous sponge showing flagellate cells and phagocytic cells.
4. Later blastula of calcareous sponge showing invasion of the cavity by flagellate cells to form scleroblasts, and by phagocytic cells to form amoebocytes.
5. Flagellate form of *Naegleria gruberi* assumed in dilute ionic solutions (e.g. <M/20 NaC1).
6. Amodboid forms of *Naegleria gruberi* assumed in more concentrated solutions (e.g. <M/20NaC1.)

INVITATION LECTURE: SECTION E

(23rd November, 1963)

COSMIC RAYS

by

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II. COSMIC RAYS OF GREAT ENERGY

1. Introduction

There are two main aspects of cosmic ray studies. The first concerns the information that is gained on conditions in interplanetary and galactic space, that is, the astrophysical aspect. In the second use is made of the cosmic ray flux to enable studies to be made of the nuclear interactions of these elementary particles. With the development of machines whereby particles may be accelerated artificially, the nuclear-physical studies of cosmic rays at low energies have been superseded. However there is still a very wide range of energy, extending from some 3×10^{10} to 10^{20} eV, over which our only information comes from cosmic rays. Further, the most common of the cosmic ray particles at ground level, the muon, is very difficult to produce artificially, even at quite low energies. It is with experiments on the muon that this paper is mainly concerned.

As in all branches of science, advances in knowledge have followed advances in technique and consideration will be given to recent developments in particle detectors.

2. The Propagation of Cosmic Rays in the Atmosphere

The general features of cosmic ray propagation can be appreciated by reference to Fig. 1. Entering at the top of the atmosphere are primary particles which have come from a number of sources, the comparatively slow particles originating in the sun and the more energetic primaries coming from such stellar objects as the Crab nebula.

In the upper layers of the atmosphere the primary particles interact with the nuclei of oxygen and nitrogen and in the ensuing nuclear disruptions a variety of unstable particles are produced. The most common are the pions, particles having a mass of 273

electron masses and a mean lifetime of 2.5×10^{-8} sec. Their lifetime is short enough for many of the pions to decay before they have chance to lose their energy by interacting with nuclei in a similar way to the original primaries. The decay products of the pion are a muon and a neutrino. Both of these particles are rather peculiar; the neutrino because it has a vanishing mass and the muon because it has no apparent place in our scheme of fundamental particles. Apart from its greater mass (207 m_e) and the fact that it is unstable (with a lifetime of 2.2×10^{-6} sec.) the muon appears to behave like an electron. One of the experimental studies to be described later will be a search for a difference between the muon and a 'heavy electron'.

In view of their comparatively long lifetime coupled with their relativistic time dilatation fast muons are able to survive, without decay, as they pass through the atmosphere, and arrive at ground level. Like the electron, the muon has only a weak interaction with matter so that only a small fraction are lost through nuclear collisions in the atmosphere.

3. Studies of Muons at Sea Level and Underground

Experiments on cosmic ray muons are in general of two main types: those concerned with the nature of the muon, and experiments in which the measurements are used to give indirect information on such matters as the characteristics of the interactions producing the parents of the muons.

The usual way of studying a particle's nature is to examine its interaction with other particles and a good deal of effort has been expended on examining the Coulomb interaction between the muon and the electron and on detecting the very weak interaction of the muon with atomic nuclei. Most of the experiments have been carried out underground where the 'contaminating' flux of nuclear active particles is cut out. Thus, in an experiment using nuclear emulsions poured and exposed in the London Underground System, Kannangara and Zivkovic (1953) showed that the μ-e collision cross-section was in good agreement with theory.

If suitable protective filters are used then experiments can also be performed at sea level. These experiments are exemplified by the work of Appapillai et al. (1954) here in Colombo. This experiment succeeded in making an estimate of the strength of the interaction between muons and lead nuclei which showed that at least at the energies in question, the muon was behaving as a heavy electron. Later experiments have confirmed this view.

3.1 The Energy Spectrum of Muons

One of the constants of the flux of cosmic ray muons at sea level is its energy spectrum. A knowledge of this spectrum enables the muons' behaviour to be analysed up to very high energy if comparison is made with the measurement of the variation of muon intensity with depth underground.

Most spectrum measurements have been made with magnetic spectrographs, in which the trajectory of a particle traversing a strong magnetic field is defined. The detectors used in these instruments were initially Geiger counters and cloud chambers but a recent advance has come through the introduction of the neon flash-tube. This technique was introduced initially by Conversi and Gozzini (1955) and was developed for use in spectrographs by the Durham group (e.g. Coxell and Wolfendale, 1960).

In this technique glass tubes filled with neon are mounted between parallel conducting plates and a high voltage pulse is applied across the plates after a selected ionizing particle has passed through the apparatus. The tubes through which the particle passed then give a flash of light which may be seen with the naked eye or recorded photographically. The mechanism of operation is that the ionizing particle produces a small number of electrons by the ionization process and these are made to produce a dense electron avalanche under the influence of the applied electric field and this in turn excites the characteristic red line in the neon spectrum.

An experimental arrangement used for testing flash-tubes is shown in Fig. 2.

A number of spectrographs have been constructed using flash-tubes and a diagram of one of these—the Durham vertical spectrograph—is given in Fig. 3. By using many layers of tubes the uncertainty of location of the track at each of the measuring levels has been reduced to ± 0.5 mm and the maximum momentum that can be measured is correspondingly high (approx. 700 GeV/c).

The measured spectra of muons and protons in the vertical direction at sea level are shown in Fig. 4 (momentum, rather than energy, is determined in the magnetic deflexion method). Momenta have been converted to energy and the intensities have been integrated to give the integral spectrum shown in Fig. 5. At energies above those that have been directly measured information comes from studies of the γ— ray cascades in the upper levels of the atmosphere and the points marked 'Duthie et al' are computed from γ— ray intensities measured by the Bristol group. The near agreement in the overlap region gives confidence in the method of computing sea level muon intensities from γ— cascade data.

3.2 The Variation of Cosmic Ray Intensity with Depth Underground

The very energetic muons at ground level are able to penetrate to great depths underground and if the measurement is made of the intensity as a function of depth the rate of energy loss of muons may be computed. Many measurements have been made underground and the results for depths greater than 1,000 m.w.e. are shown in Fig. 6 (1. m.w.e. = 100 g. cm^{-2}). The most recent observations are those due to the Bombay group working in the Kolar gold fields (Miyake et al., 1962, Ramana Murthy, 1962). These workers used scintillation counters operated in coincidence and at the present time these detectors are being augmented by flash-tubes from Durham so that a clear visual record may be made of the very rare particles present at great depths. An interesting consequence of the very rapid fall-off in intensity with depth is that at the greatest depths there should be events detected due not to muons which have penetrated the whole of the overlying rock but to muons generated locally by the interaction of cosmic ray neutrinos. Since the interaction of the neutrino is incredibly weak the neutrino flux underground is nearly isotropic compared with the direct muon flux which is strongly collimated in the vertical direction. Use is being made of this difference in the Kolar experiments by searching for muons which are travelling almost horizontally. The resulting numbers of events will be used to estimate the strength of the neutrino-nucleon interaction—a quantity of great interest to the fundamental particle physicist.

To return to the energy loss problem. The data given in Figs. 5 and 6 have been used to determine the rate of energy loss and it has been found (by Hayman et al., 1963) that there is good agreement with the rate of loss predicted under the assumption that muons behave like heavy electrons. Thus it is clear that even for energies as high as 5,000 GeV the muon is not showing any unusual behaviour; the paradox of its existence remains.

4. The Energy Spectrum of Primary Cosmic Rays

With the recent measurement of comparatively accurate spectra of muons and protons at sea level it is possible to draw quantitative conclusions about the primary spectrum if a model is assumed for the interaction between a nucleon and a nucleus. Essentially, the proton spectrum at sea level gives information about the energy retained by the nucleons and the muon spectrum indicates what fractions of the energy lost by the nucleons is given to the parents of the muons.

4.1 Models for high Energy Interactions

As yet, no model has been proposed for the nucleon-nucleon interaction which is capable of explaining all the observed features. However, in the present analysis the final result is not very sensitive to the interaction model and an empirical model due to Cocconi et al. (1961), which is valid in the tens of GeV region, has been taken to apply to the high energy region in question. In this model, the relation for the number of pions of one sign emitted in the forward direction in the C-system, $N(E\pi)$, for an interaction between a nucleon and a light nucleus, is

$$N(E_n)dE_\pi = \frac{A}{T_p} \exp\left(-\frac{E_\pi}{T_p}\right) dE_\pi$$

where $E\pi$ is the energy of the pion in the L-system, A is the mean multiplicity of pions of one sign emitted in the forward direction in the C-system and T_p is the mean pion energy. The relation between these quantities and $K\pi$, the energy given to pions of all charge states is $AT_p = \frac{K_\pi}{3} E_p$

There is strong evidence that the multiplicity varies with Ep as $E_p^{1/4}$, and, numerically $A = 0.45_p^{1/4}$.

4.2 Determination of the Primary Spectrum

Brooke et al. (1963) have determined the primary spectrum which fits the sea level data in the following way. A trial primary spectrum is taken and the values of the total inelasticity of nucleon-air nucleus interactions, K_t, and the fraction of energy appearing as pions, K_t, are determined which lead to the observed sea level spectra. The trial spectrum is taken from the work of Linsley et al. (1962) (who used the data of other workers in the energy region in question) and using this spectrum the resulting values of the inelasticities are as shown in Fig. 7. The difference between K_t and $K\pi$ is far greater than can be accounted for in terms of known processes; experiments indicate that $K_t - K\pi$ approx. 0.12 and the conclusion to be drawn is that the true primary spectrum has a lower intensity than that assumed in the calculations.

The amended integral spectrum is shown in Fig. 8. This spectrum together with the condition $K_t - K\pi$ approx. 0.12 and the nuclear interaction model of Cocconi et al. leads to sea level spectra of muons and protons which agree with what are found experimentally. Also shown in the figure is the trial spectrum from the work of Linsley et al. Above the energies considered here the intensities are derived from the measurements on extensive air showers and significant uncertainty in the intensities would not be expected.

4.3 Discussion of the Primary Spectrum Determination

If the analysis given above is correct then there is clearly a rapid change in slope of the primary spectrum in the energy region $10^5 - 10^6$ GeV. Such a change has important cosmological implications. There is the well known difficulty of explaining the presence of the cosmic rays of highest energy (say approx. 10^8GeV), because of the inefficiency of the weak galactic magnetic fields in trapping such particles, and it is tempting to suggest that there is a transition in the region of $10^5 - 10^6$ GeV from intragalactic to extra galactic sources. A further examination of both the data and its interpretation should be rewarding.

5. The Spark Chamber

Finally, some mention will be made of a recent technique which promises to have wide application in studies of high energy cosmic rays. This technique, the spark chamber, was developed by Fukui and Miyamoto in 1959 from experiments on neon flash-tubes. By reducing the length of the high voltage pulse to a fraction of a microsecond the discharge can be reduced to a narrow spark along the path of the particle. This means that the glass envelope of the flash-tube can be dispensed with and the electrodes mounted inside a vessel containing the neon gas. A typical arrangement is shown in Fig. 9.

The spark chamber has already found wide application at the high energy accelerators; probably the most important advance in nuclear physics in the last two or three years—the discovery of a difference between the muon and electron neutrinos—was made using their technique.

Studies are being made at the moment with the object of constructing a magnetic spectrograph comprising spark chambers, in which the need to photograph the sparks is avoided by taking pulses from a series of fine wires which form one of the electrodes of each chamber. Such an instrument will have wide application in cosmic rays, not only for measurements at sea level but also for studies of the primary particles through miniature spectrographs mounted in satellites.

Acknowledgements

The author is grateful to his colleagues at Durham whose work forms the basis for most of this paper.

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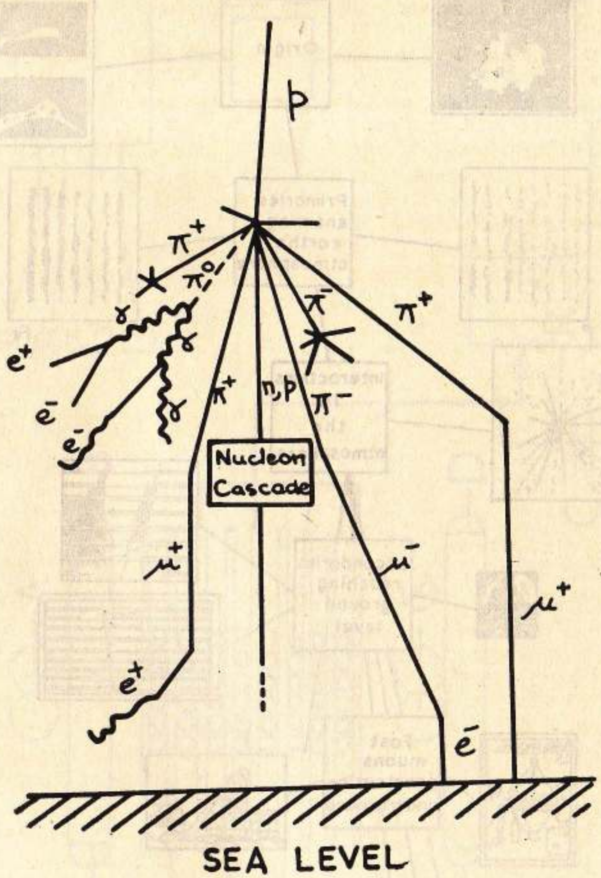

Fig. 1.
The propagation of cosmic rays through the atmosphere.

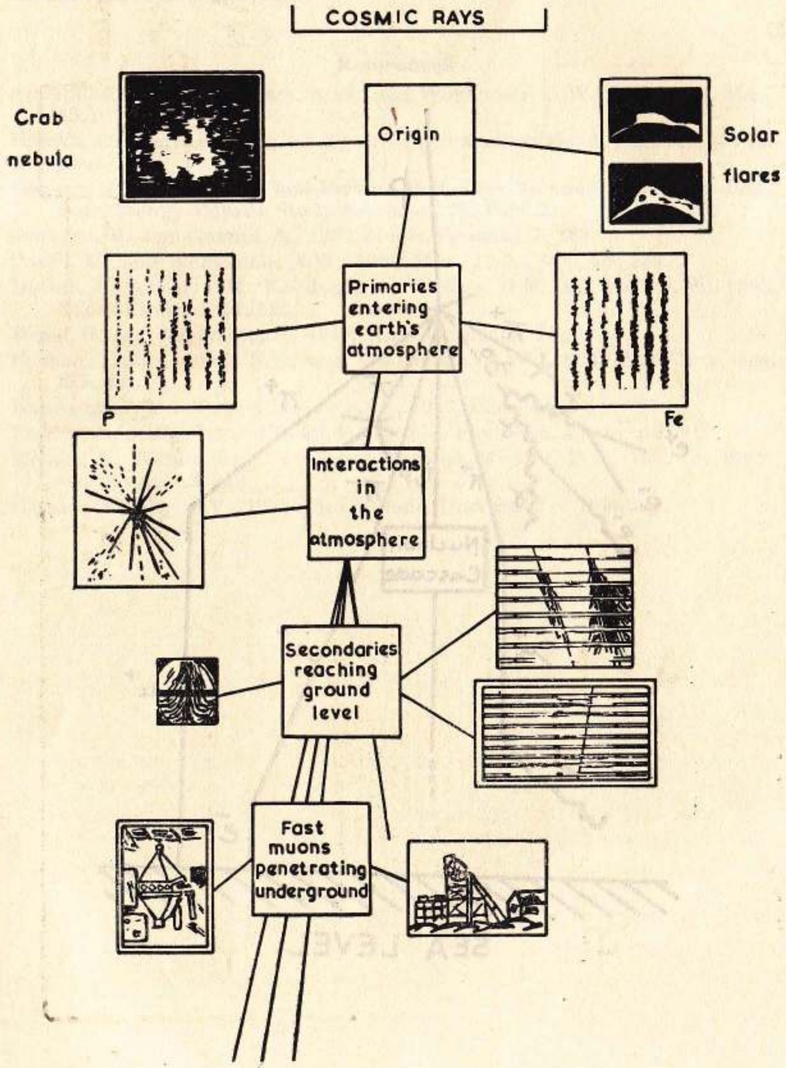

Fig. 1A.
Cosmic ray investigations in the atmosphere.

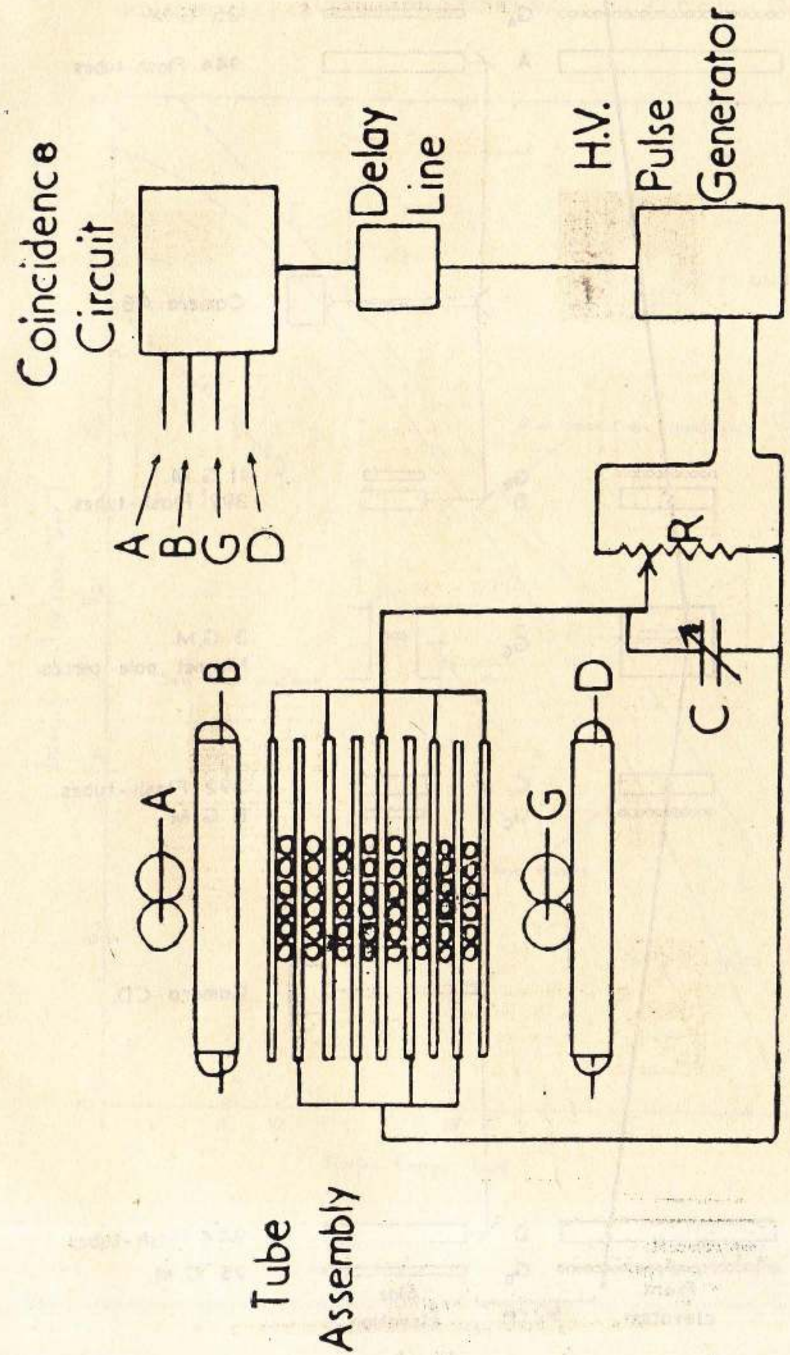

Fig. 2.
An experimental arrangement used for testing neon flash-tu bes.

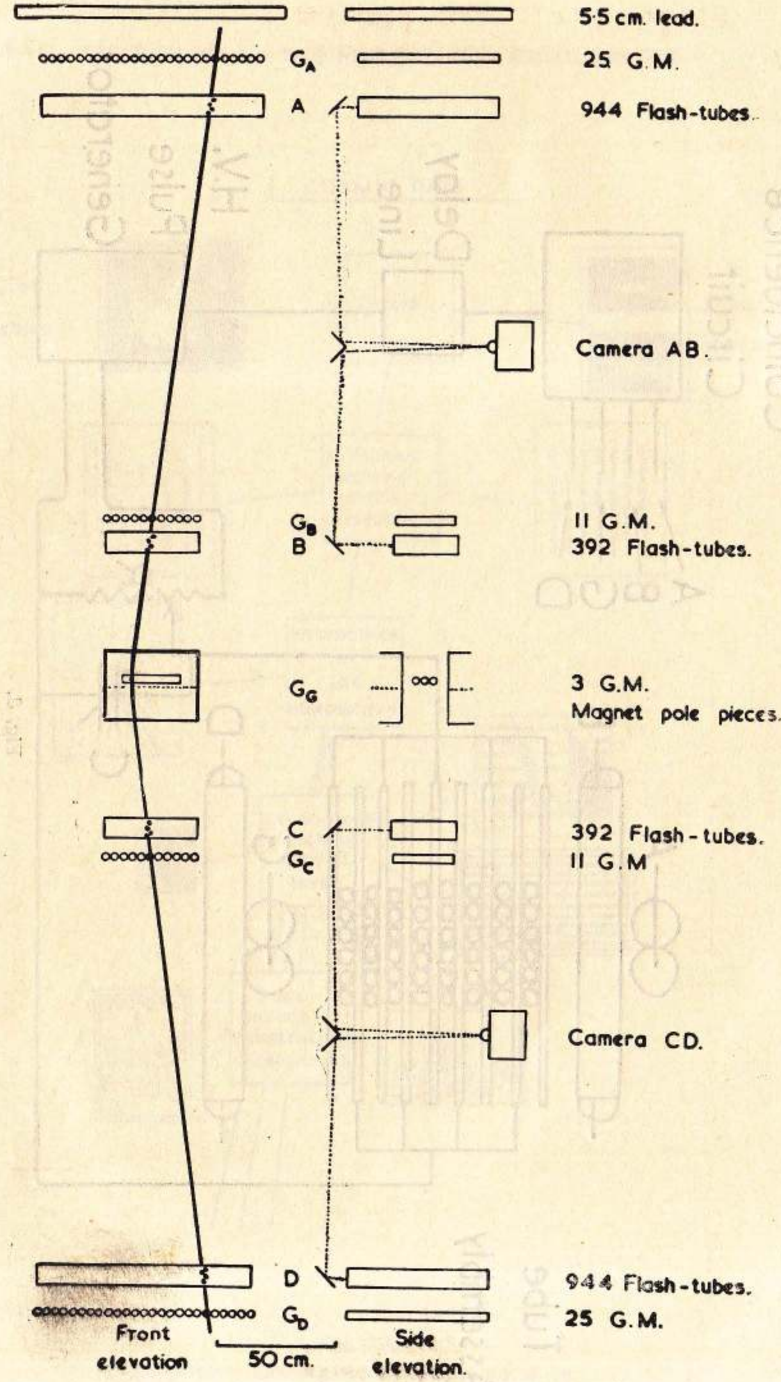

Fig. 3.
Schematic diagram of the Durham Vertical Cosmic Ray Spectrograph.

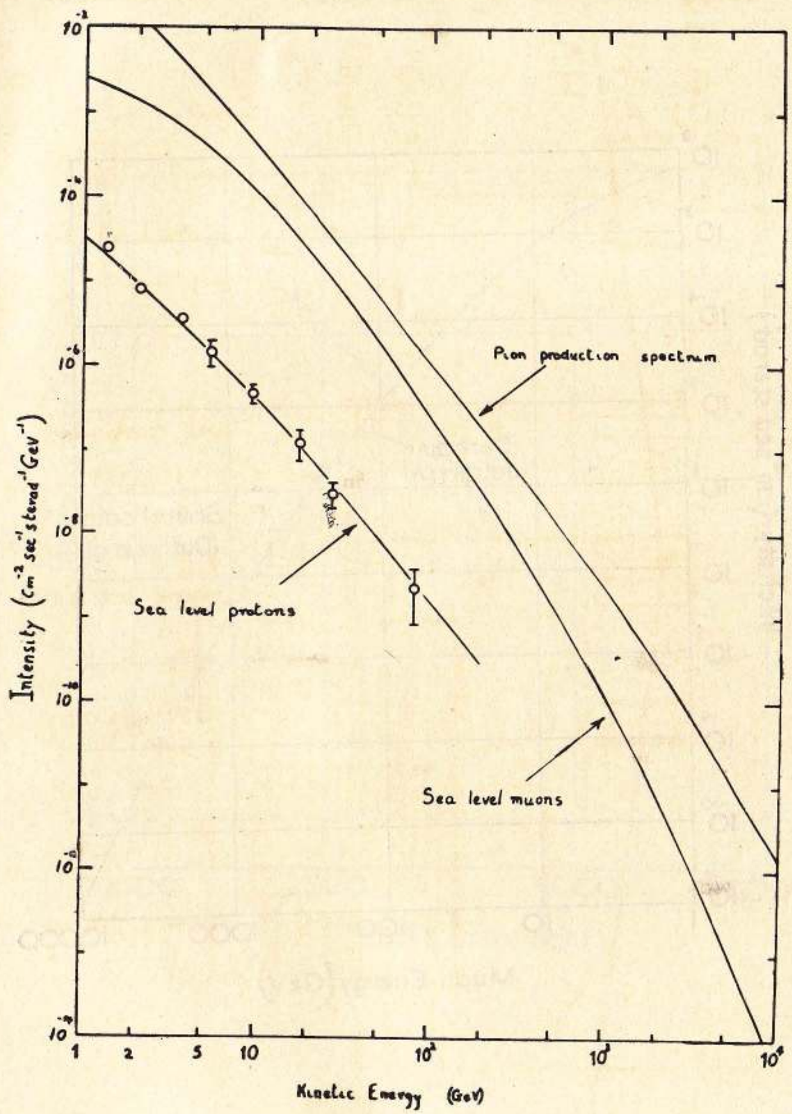

Fig. 4.
The momentum spectra of muons and protons in the vertical direction at sea level (Brooke et al., 1963).

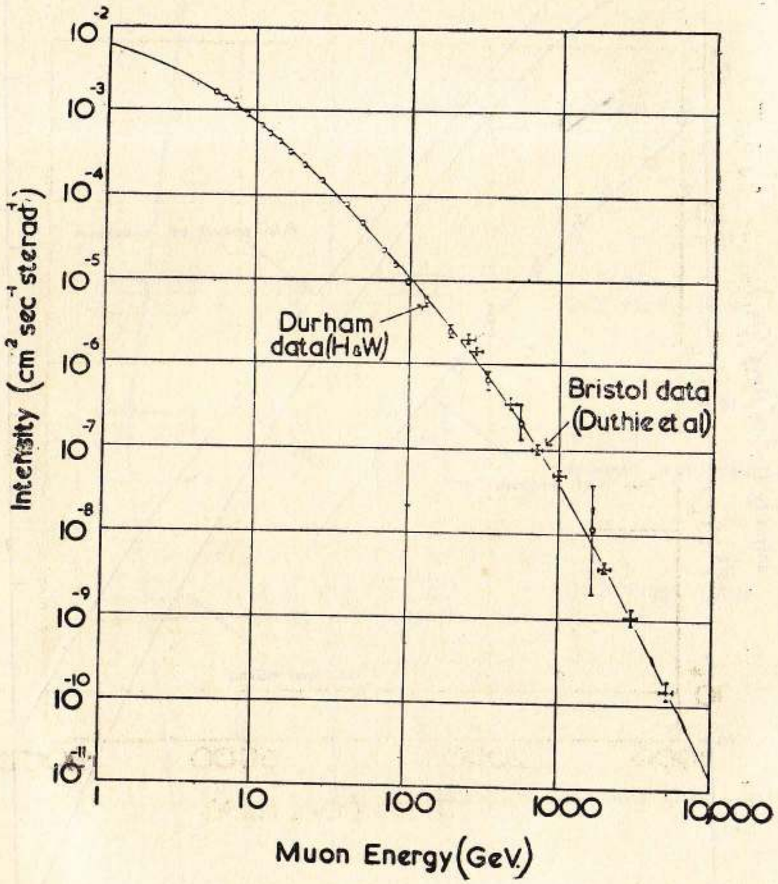

Fig. 5.
The integral energy spectrum of muons in the vertical direction at sea level (from Hayman et al., 1963).

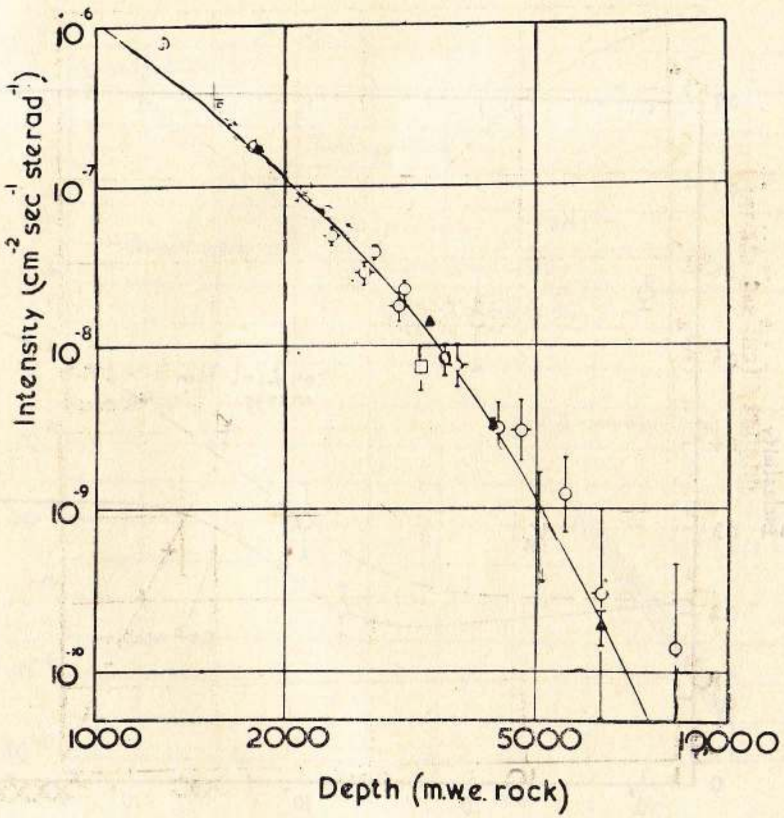

Fig. 6.
The variation of the vertical cosmic ray intensity with depth underground (from Hayman et al., 1963).

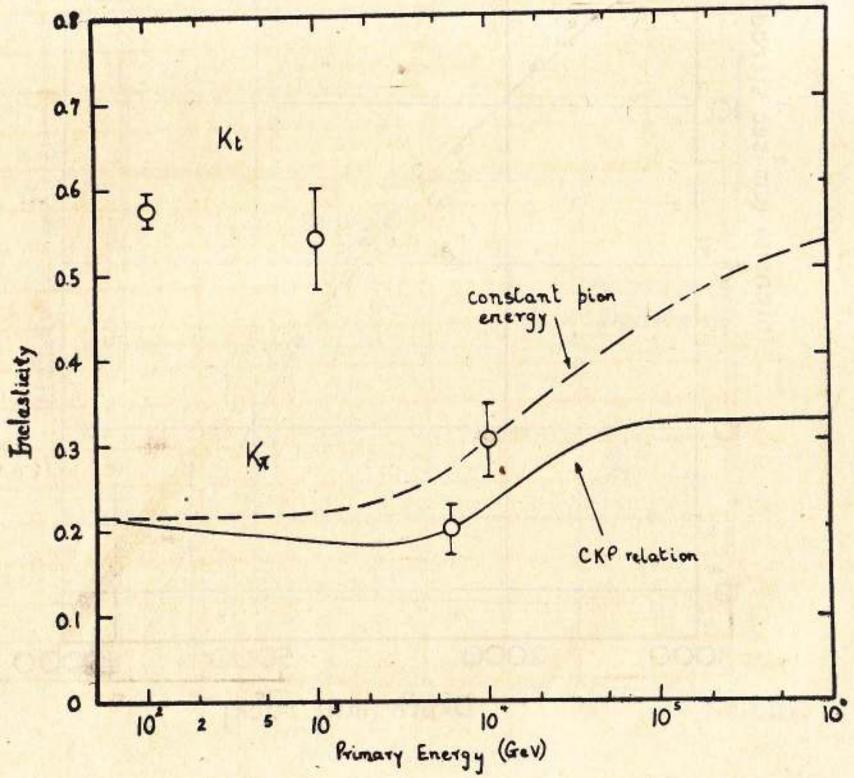

Fig. 7.
Inelasticity values found using the trial primary spectrum.

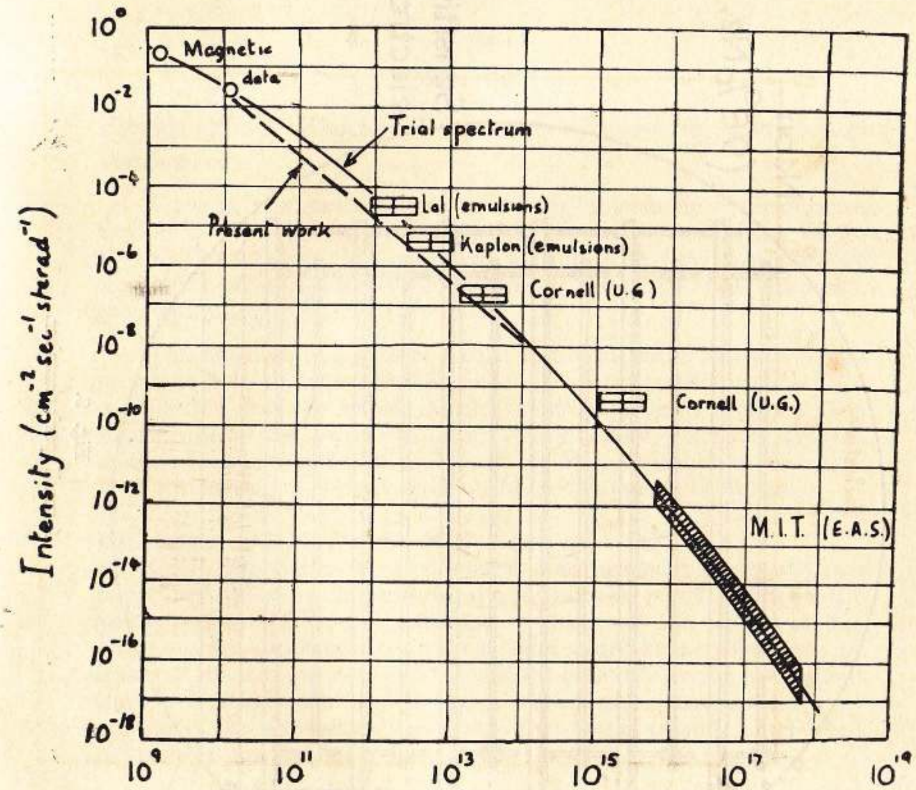

Fig. 8.
The integral spectrum of primary cosmic ray nucleons.

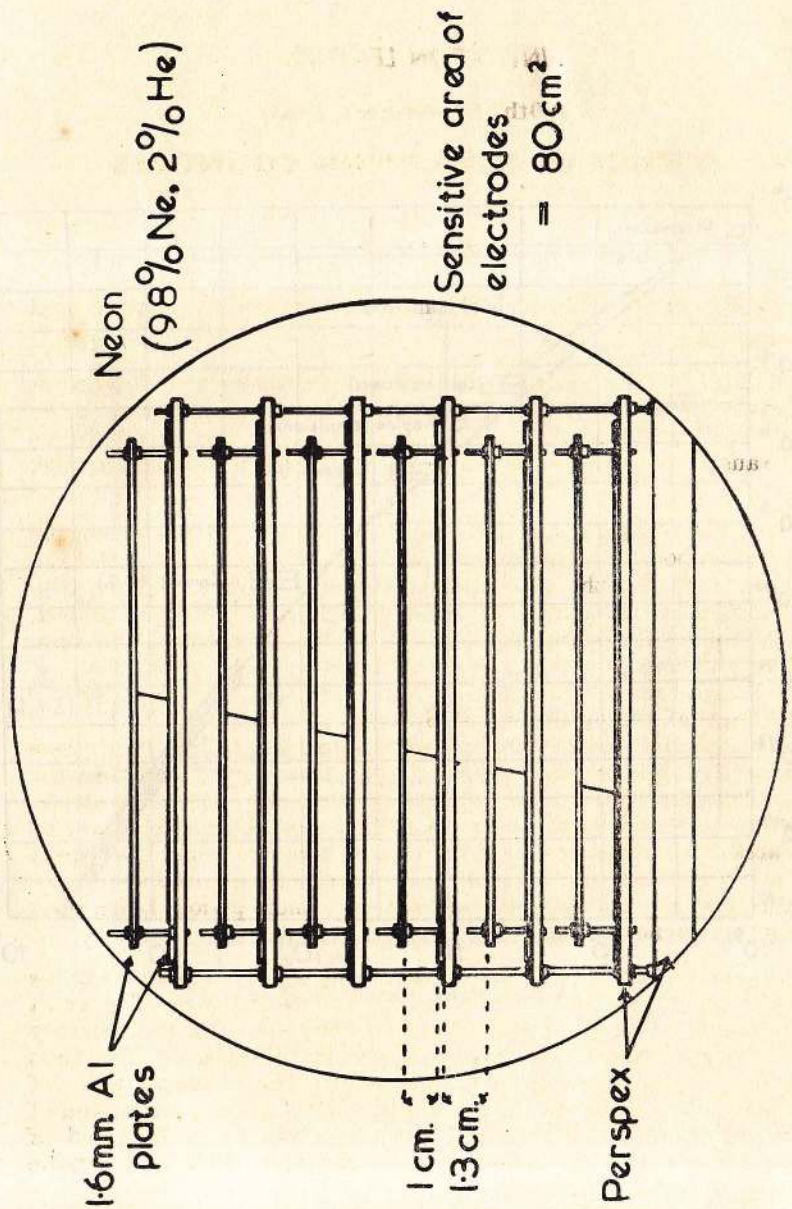

Fig. 9.
A small spark chamber.

INVITATION LECTURE

(20th November, 1963)

SCIENCE IN DEVELOPING COUNTRIES

By

K.L. RAO*

Hon'ble Prime Minister, Distinguished Scientists, Ladies and Gentlemen,

I thank the Association for the Advancement of Science in Ceylon for the signal honour they have done me in inviting me to be the Chief Guest. We are most fortunate in having amidst us the august personage of Hon'ble Prime Minister, Mrs. Bandaranaike, the great missionary of peace.

This Association of Shri Lanka is unique as it has among its members both scientists and engineers. This is proper for both have contributed for the rapid development of science. Science is a summation of the secrets of nature, assiduously, patiently probed, analysed and categorised and used by Man throughout the ages. It is interesting to briefly review the development of Science.

History of Development of Science

Geologists tell us that this earth was formed billions of years back, and that the first life to arrive was the plant and then the animal. Man, the wonder machine of God, was the last to arrive. Even so, he appeared about 25 million years back. There are no traces of his achievements in the distant past. He might have spent time in fighting with his fellowmen, beasts and nature for his very existence. But this would have been for a short period. Later what happened is not known.

The earliest period from where we have proved glimpses of his development pertains to about six thousand years. The great Pyramids of Egypt were built about 2800 B.C. with the accuracy of modern science, the angles of corners differing by less than 1/300th of a degree from a right angle. The historical relics of Mohenjadaro, Nalanda, Nagarjuna Konda of ancient India, and of the works in the Tigres and Euphrates valleys in Iran and of irrigation works in Ceylon indicate the high skills and artistic tastes of early civilisation.

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Recently, I visited Egypt for looking over the High Aswan Project currently under construction. This dam will submerge temples in the gorge section of the River Nile above Aswan. Of these, two are most famous, Abbu Simbel and Kulabaksh. Abu Simbel consists of large figures of twenty feet height and columns carved out of virgin rock. To save it from submergence, various alternative plans were drawn up. At one stage, it was even considered to cut out the portion of the mountain where the temple is located and to lift the entire structure intact, with the temple, above the full reservoir level. This was considered too costly and now it is decided to cut the carvings into parts and assemble them at the top. The Kulabaksh temple was of a different type. Outside walls and inside portions were all built of carved individual stones. Therefore, it was easy to dismantle them all, transport them to the new dam site and reassemble them. This was nearly completed at the time of my visit.

When one sees such excellent carvings, one cannot but admit that there must have been a great civilisation in the distant past. The walls consisted of an outer row, with an inside filling of stones. Some of the stones used for the inside filling showed remarkable carvings indicating an even earlier development. It is certain that the King who built the Kulabaksh temple must have dismantled an existing one and used the stones for mere filling.

The ancient scriptures of the Hindus and Buddhists and Christians give indications of the sublime heights to which Man has risen in philosophical and metaphysical fields. Even in engineering fields such as combating the flood damages due to rivers, measures seem to have been developed with resemble closely those of modern days. Thus, in Uttar Pradesh in India, where Lord Buddha lived and preached, Himalayan rivers cause yearly floods and inundate vast areas of lands and habitations. Among the various measures adopted to overcome the difficulties, constructing villages on filled earth mounds is one. The same method seems to have been adopted in the days of Lord Buddha, for in Dhammapada, it is stated "By effort, earnestness, discipline and self-control, let the wise man make for himself an island which no flood can overcome".

From 3000 B.C. to the 17th century after Christ, development was mainly in the field of abstract reasoning. Experiments and proofs were considered too elementary. Mathematics made a marked advance. Euclid's geometry was formulated in 300 B.C. Archimedes (287-212 B.C.) was another great mathematician of these items. He invented the science of hydrostatics, principles of levers, etc. A few experiments if done, were only to serve as a scaffold for building up higher mathematics.

Aristotle (384-322 B.C.) was the greatest Philosopher of this period. He enunciated on so many aspects of life—morals, law, politics, philosophy and the ways of life that they are as true and fresh today as when he observed them more than 2000 years ago. For instance, his sayings like the following are fresh and true today as at the time of utterance:

"Democracy arose from men's thinking that if they are equal in any respect, they are equal absolutely".

"The roots of education are bitter but the fruits are sweet".

"There was never a great genius without a tincture of madness".

"Revolutions are not about trifles, but spring from trifles".

As Aristotle used only his powers of thinking and not that of any observations and experiments, some of his conclusions on nature were highly erroneous. He said that the world consists of earth, air, fire and water. "Put a log in the fire, you will see water oozing out of the end; smoke will issue, which is a short of air, flames will appear, which are fire; and ashes will be left which is earth. So there are earth, air, fire and water in a log". According to him, moon was of a different substance. Similarly, he said that the speed of a falling body was proportional to its weight and air had no weight.

Aristotle was such a great genius that his statements went unchallenged for several centuries.

At the beginning of the seventeenth century, there was a change in outlook. Man began to realise the importance of observations and experiments both in the laboratory and the field. This approach resulted in considerable advance in sciences resulting in gaining a deeper knowledge of nature. Indeed the depth and extent of knowledge man had gained earlier to 1600 A.D. is almost negligible compared to what he has gained in these last three and a half centuries. Galileo (1564-1642) A.D. was the first scientist and practical engineer to usher in the modern scientific age. He disproved the postulates of the earlier Greek philosophers and founded a new science based on practical observations and experiments. Though he was a great mathematician, he intensively believed in practical observations and experiments. He showed by experiments on inclined planes and by dropping weights from the top of a tower that the speed of a falling body is not proportionate to its weight.

He proved that Aristotle's concept that air had no weight is wrong. He took a bottle and fitted it with a valve and inserted a rubber tube into the bottle. Then he poured water into the tube thereby compressing the air in the bottle making it occupy a smaller space. He weighed the bottle. Then he opened the valve and let the air escape. He put back the valve and then weighed it again.

The loss represented the weight of the air equal in volume to the water in the tube. Thereby he proved that air had weight. He had to resort to this as vacuum pumps were not invented by that time. Similarly he discovered from observations of swinging lights in a church that a pendulum of a given length swings the same number of times in a given interval, no matter whether the breadth of the swing is large or small. This led to the invention of clocks later. Similarly, he was the first to use a thermometer for showing changes of temperature. He invented the telescope and used it to scan the sky. According to Aristotle the moon was a perfectly smooth sphere composed of a fifth element unknown on earth. Galileo showed it to be otherwise. By studying through his telescope the dark spots and lines of light, he argued that the moon was a rugged body, made of the same material as the earth. His conviction for saying that the earth is moving round the sun is well known. Some of his observations are fresh and apply even today in spite of a huge amount of research done. Thus in respect of the laws of flow of water, there are still uncertainties and in spite of a vast amount of hydraulic research being conducted for the last hundred years in various countries of the world, the subject remains obscure. On this Galileo observed that while he was able to detect minute differences in heavenly bodies, several millions of miles away, he was not able to comprehend the laws of flow of nearby water. That this observation should remain true even today speaks of the genius of the great man.

It may be an accident that he was born in the same year as Shakespeare and died in the year in which Issac Newton was born, but it is significant. I am reminded of another interesting coincidence. The scientific age seems to have been ushered in with the completion of the Taj Mahal in 1630. The Taj Mahal represents the skill and artistic tastes of the pre-scientific age. That the building stands in vivid freshness today as at the time of construction and draws admirers from all over the world is evidence of the capabilities of the earlier Man. His intellectual attainments were as great as ours, but not having the advantage of the new approach of ascertaining facts through experiment, he could not penetrate the secrets of nature as rapidly as we are doing at present.

After Galileo, there were many contributors to the newly developed scientific technique. Though ideas were continually changing, there was greater insight into the laws of nature. Thus in 1820 light was regarded as consisting of particles while a hundred years earlier it was thought of as waves in ether and now we think it has the properties of both. Einstein has shown that light beams get bent due to gravitational fields. Similarly the first concept of electricity was that it was of two kinds, but later Benjamin Franklin proved by experiment that electricity was of only one kind. Similarly

various sciences like Chemistry, went on developing from primitive stages. Flow in channels remained a qualitative item till Pitot discovered through observations the method of measuring velocities with a tube. He wrote thus: "The idea of this machine is so simple and natural that the moment I conceived it I ran immediately to the river to make a first experiment with a glass tube, and the result confirmed completely my anticipation. After this first experiment, I could not imagine that such a simple and at the same time very useful thing could escape so many skilled people who have written and worked on the motion of rivers". This serves to show that it is not elaborate equipment or buildings that are necessary to register progress of science, but it is determined pursuit and concentrated thinking that are necessary.

Experiments covered all fields including the study of living beings. Lavoisier discovered that "Life is a chemical function". This led to the present concept of the necessity of providing a certain minimum quantity of calories and vitamins to get work out of the human machine.

One of the great discoveries of the new age is the concept of energy and the conservation of energy. With this, it is possible to explain many phenomena. Thus it is now established that the Sun is not merely a hot body radiating its heat energy, cooling down like a red-hot poker in the process, but that it is slowly contracting under the pull of its own gravitation. The work done by its vast mass falling towards its centre represents a heat equivalent enough to maintain the present rate of supply for twenty million years.

A discovery of great importance is that of waves of high frequency varying up to 30 million cycles per second. These were discovered through experiments on the remarkable appearances that were manifest when electricity passed through gases at low pressure. These high frequency waves are used in telecommunication and radio communication.

Another great event was the discovery of photography and use of hypo (sodium thiosulphate) as a fixative in the early 19th century.

The discovery that gases, through a process of cooling, compression, or both, can condense into liquids just as steam can be formed into water through similar process has found many valuable applications. Gases like nitrogen, oxygen and hydrogen are separated by liquefication and by fractionation. These have given rise to the manufacture of oxygen and ammonia for various industries, like fertilisers, heavy water for atomic energy, etc. It has become possible to attain extremely low temperatures approaching absolute zero through the compression and expansion of gases.

The recent discoveries of rockets, turbojets, computors, automatons, etc. indicate the rapid pace of the new scientific age.

Thus the present technique of science involve experiment, theory and inductive reasoning. Nothing done previously in science is lot. Men of each generation passed on their observations to the next one and science has grown through the ages by collective effort. As stated by Newton, science grows on the shoulders of the earlier giants. The vast canvas of science is being continually filled in, may be in isolated patches, by various painters at different times and one day, the canvass will be fully covered.

Science—Its Impact in Life

Scientific development in the last three centuries can be divided into two broad classes—pure science and applied science. Pure science aims at fresh thinking and leads to discoveries. It does not have a direct bearing on the daily life while the second category of science, i.e. applied science, completely influences the mode of life. The second category is also known as engineering and technology. The dominating influence of this technology under modern life is so great that in this modern age it can be said that we are living in a Technocracy instead of a Democracy. Whatever we use in our life right from the early morning till we go to bed, everything is an application of science. Man has applied science in getting benefits from nature according to the circumstances. The sciences are the languages of nature and the engineers have used it in understanding nature.

In Holland, there is not sufficient land for its ten million people living in the country. So the engineers thought of recovering land from the sea by constructing a 20 mile dam at a suitable place and pumping out the water from the enclosed space. It has been possible to recover 10 lakh acres from the sea bed for agricultural purposes. This project is known as the Zuider Zee project and is testimony to the engineering skill of the Dutchmen. Here is an example of the recovery of land from the sea.

In Washington State of U.S.A., there are vast fertile lands to be cultivated, but the rainfall is scanty and water has to be supplied. The lands are at a height of nearly 1000 ft. above the bed of the river Columbia which passes through the State. Engineers constructed a dam called the Grand Coulee Dam, a magnificent structure which is about 550 ft. high above the bed of the river. Electrical power is produced at the dam and a portion of this power is utilised to lift the water to a further height of 400 ft. so as to irrigate the uplands in Washington State. Ten lakhs of acres are thus irrigated. This is an example where scientific development has made it possible to utilise lands higher than that of the river bed.

Million of people were dying out of famines in the Godavari and Krishna deltaic areas only a hundred and fifty years back. While magnificent rivers were passing by, parched lands were thirsting for water and crops failed. Sir Arthur Cotton, a great British engineer constructed weirs across the rivers, raised the water to flow on the lands, thus converting famine tracts into one of the richest regions of the world.

There is the example of the river Nile. Egypt is a dry country where the rainfall is hardly an inch in five years, specially in the upper regions of Egypt. In bringing irrigation waters for millions of acres, utilising the Nile waters to the utmost, Man's ingenuity has been demonstrated in the conquest of nature. Not satisfied with the achievements in the past, a higher dam is being constructed at Aswan, which will completely bottle up the entire Nile flow and thus enable a very large exploitation of the river for the benefit of Man. Similarly the complete transformation that is taking place in Siberia into a first rate country instead of a "nature's coffin", as it was considered earlier, would not have been possible except for modern science.

The greatest discovery of science which has permeated our life completely is the generation of electrical power by using the principle of magnetic induction. Practically, the prosperity of a country completely depends on power. The total power generated in the world today is firm installation of 550 million kilowatts. Of this, U.S.A. has an installed capacity of 198 million kilowatts; USSR—74 million kilowatts; and other European countries have capacities varying from 4 million kilowatts in Austria to 30 million kilowatts in Germany. In India we have nearly 7 million kilowatts forming 1.3% of the total of world capacity. Power is generated in many ways; the cheapest, of course, is through hydro projects. Power can also be produced through utilisation of coal energy. Coal is burnt; water is converted into steam and steam is passed through the turbines. Thermal stations are becoming increasingly larger and larger in size. Another mighty source of energy, waiting to be tapped, is the tidal power. In France, which I happened to visit in 1960, a quarter million kilowatts are being generated at La Ranse by making use of the tides. The high tides run into the river mouth. Their return is prevented by a barrage and when the sea tide gets into the ebb stage, the water is released from the reservoir and power is generated. By ingenious application, it has been possible to make this power even continuous. There are favourable estuaries in India where this method can be used. For example, at Bhavnagar in Saurashtra, we have a tidal range of about 40 ft.

The other source of power production is through utilisation of atomic energy. England is exploiting this for production of nearly five million kilowatts by 1968. In India, we are making a beginning. At present moment generating atomic power is costlier than other types but with improvements and due to inadequacy of other sources, it is almost certain that atomic energy will come to be the main source of power production along with hydro electric power, in the next fifty years.

Attempts also are being made to convert solar energy into electric power.

Sufficient amount of electricity has been generated in the USSR from solar energy to make use in running of trains. But it has not become widely popular as yet. People in tropical countries like ours must take it up seriously. If successful, we shall have an immense source of energy for producing power.

Science: Its Relationship with Religion

The scientific age has come with suddenness and this has a profound effect on man's nature and behaviour. Man builds up his character based on religion but science with its emphasis on experiments has disturbed him. Einstein has observed that science without religion is lame, but religion without science is blind. This perhaps represents the general mind of the present day scientist. But in view of the dangerous situations that science is capable of creating, it is essential that moral values of religion have to be more deeply implanted in Man. To this extent, there is a greater necessity for religion than at any other time in the history of man.

Science seems to deal impartially with both good and bad. I will illustrate what I mean by a few simple examples.

Isotopes which are radio-active for a limited period are extensively used in civilian activities. Thus at Bombay Harbour, a deep channel is dredged throughout the year and the dredged material is dumped at a certain place in the sea. But it happens that all the material comes back to the harbour year after year. Therefore, to determine a proper dumping ground so that the material may not come back, an experiment was conducted. Radio isotopes were dumped in a suitable place and were traced with a Geiger counter. The experiment was repeated with different locations of dumping grounds.

From these experiments, a proper place from which no material comes back has been determined. Thus the radio isotopes have helped in tracing correctly the movement of silt and in fixing the proper dumping places.

Scientific technique is being used to solve very difficult problems. At Mangalore (in India) a port was to be built. The river called Netravati joins the sea south of Mangalore. The question was whether the silt of the river is being carried south or north, for, on it depended the location of the port. Technical opinions were equally divided. Some argued that the port should be south of the river, while others said it should be on the north. If wrongly located, it would have involved a very large amount of dredging. In order to determine this question and to settle the controversy, sand was coloured with 'Flurol', a colouring compound specially obtained from Germany. Thus coated, sand does not lose colour under water and shows up differently under ultraviolet light. A quantity of this coloured sand was dumped in the river mouth and after a fortnight, bed soil samples were taken from both southern and northern areas and microscopic examination was made under ultraviolet light to find out the presence of the coloured sand. The coloured sands indicated that the silt of the river was going down south. Hence it was decided that the port should be located north of the river. Thus these scientific experiments are extremely valuable.

Science is also used for the disadvantage of Man. It is sad to reflect that science developed greatly as a result of the two recent wars. At the end of the last war, an atomic bomb was dropped at Hiroshima. I happened to visit this place two years ago. The place was completely destroyed by the atomic bomb. In the vicinity of the burst even the stones had melted. These bombs attain temperatures of nearly 300,000° C—50 times the surface temperature of the sun. Thus we find that science is capable of doing both good and bad for Man.

Conclusion

The world can broadly be divided into two sections—the developed countries and the developing countries. The developed countries probably form 1/5th of the world population and occupy 2/5th of the land area of the world. The developed countries have the advantage of high technological utilisation of the various natural resources, minerals, trained personnel and the advantages that accrued to them from an earlier start. The developing countries suffer for want of finances, trained personnel, knowledge of science and want of even adequate food and power. In spite of these handicaps, the developing countries have to come up if hunger, misery and ignorance are to be banished from this world. With the highest development of science and technology, if this much is not done, there will be no justification, one can say, for the world to exist. With the great advances in science and technology, the achievement of enough for all is no longer a miracle. To ensure rapid development of science in emerging countries, I venture to summarise a few thoughts.

(i) It is necessary to create a scientific climate, a mass appetite for science in the less developed countries, without which it is impossible for science to flourish. Advanced countries have passed through this stage. Dr. John Russel's observations are worth noting in this connection:

> "In 1870 and 1880 my father had some chemical and electrical appliances with which he would entertain us at times. My mother always insisted, however, that the chemical experiments must be confined to the kitchen sink. They were, of course very elementary and, no doubt, very crude, for he had no proper scientific training, but they gave us an *abiding* interest in experimental science".

It is necessary for us in the developing countries to put on the market a large number of simple books, appliances, chemicals, etc., and create interest among the general public in scientific matters. We have to teach science attractively in schools. We have got to organise popular lectures and exhibitions to be understood by the masses in general, for they form the electorate in a democracy and the complexion and scientific attitude of Government will depend upon their choice.

(ii) Encouragement of scientists and engineers is of the utmost importance to the developing countries. It may not be so in the developed countries. But in the less developed countries, economic advance is entirely dependent on science and it is essential for the Government to ensure as much encouragement as possible for scientists and engineers. In India, we have a Scientific Resolution passed by the Parliament. This is quoted below:

(i) "to foster, promote and sustain, by all appropriate means, the cultivation of science, and scientific research in all its aspects—pure, applied and educational,

(ii) to ensure an adequate supply, within the country, of research scientists of the highest quality, and to recognise their work as an important component of the strength of the nation;

(iii) to encourage, and initiate, with all possible speed, programmes for the training of scientific and technical personnel, on a scale adequate to fulfil the country's needs in science and education, agriculture and industry, and defence;

(iv) to ensure that the creative talent of men and women is encouraged and finds full scope in scientific activity;

(v) to encourage individual initiative for the acquisition and dissemination of knowledge, and for the discovery of new knowledge, in an atmosphere of academic freedom;

(vi) and, in general to secure for the people of the country all the benefits that can accrue from the acquisition and application of scientific knowledge".

This recognises the importance of scientists and engineers in the country. This, of course, has to be substantially implemented. Continuous thinking is being given to it. It is suggested that scientists should have graded scales and their salaries should be adequate and attractive.

Due recognition has to be given to encourage the scientists. The best example of success achieved thus is in USSR. Probably next to Ministers, engineers and scientists are the most respected men in the USSR. In spite of facilities offered, we find quite an appreciable number of our scientists go to USA and Europe to settle down there. The reasons for this may be better wages and better living conditions in advanced countries. It may be even better facilities for doing research work and more liveliness. It is no doubt true, they are contributing to World Science. But the more important duty—in my view, the only duty—that the scientist of a country should do, is to work for the needs of his underdeveloped country. We must create an army of scientists.

(iii) Science and engineering have to many disciplines that it is no longer possible for any one laboratory to cater for all. It is obvious that there should be a large number of laboratories in a country. Thus in India we have 27 National Laboratories starting with Physics and Chemistry, going on to electronics. These laboratories cover fundamental as well as applied sciences—fuels, drugs, ceramics, metallurgy, building, leather, food, roads, aeronautics, mechanical engineering and similar important subjects.

Again in the field of irrigation research itself there are 20 laboratories in India. There are different laboratories specialising in different subjects like studies of tides in Poona, seepage flow in Madras, and river training works in Punjab, etc. In order to ensure that there is no overlapping and there is complementary type of research, it is essential to have a co-ordinating body, both on the administrative side and on the technical side. In India, we have the Central Board of Irrigation and Power, the Council of Scientific and Industrial Research, and the Indian Council of Agricultural Research. These organisations are of a unique type. Thus the Central Board of Irrigation and Power has nearly a hundred Chief Engineers of Electricity and of Irrigation as members. The Council of Scientific and Industrial Research is an autonomous organisation with the Prime Minister as President and the Minister of Scientific and Cultural Affairs as Vice-President. On its governing body, are represented men of Science from universities, the Ministries of Finance and Industry, and leaders of industry.

The Indian Council of Agricultural Research is an attached office of the Ministry of Agriculture with an Advisory Council made up of representatives of all related interests.

(iv) The less developed countries, in view of thier limited finances and trained personnel, will not be able to mount up research to that extent and intensity as in the developed countries. Thus the U.S.A. is spending on fundamental research in the universities alone Rs. 500 crores per year. The other day, I attended in Berlin a symposium and an Exhibition on water utilisation and water supply. Purification of water before it is led down into the river is one of the major problems on which German engineers are engaged. In order to acquaint the public, an exhibition was arranged in which nearly a crore of rupees was spent. It was very useful to go round this exhibition. For example, I saw cast iron pipes being exhibited to show how with the new method of casting iron pipes do not break under tension. A big weight was dropped and the pipe did not break but only yielded as in steel pipes. This they told me was due to the discovery of a new way of casting in which graphite particles were laid in a particular way. Thus, the developed countries having vast resources, finances and technical personnel, are going ahead with extensive research in specialised fields.

It is to be particularly understood that no country can come up merely by adopting results obtained in other developed countries. Sound technical knowledge has to be gained by extensive researches. Therefore, the developing countries have to organise a large number of laboratories to go through the various stages of development, and for this substantial training of personnel is most essential. For our region, we may establish some selected laboratories in a few places, equip them with the most modern equipment and employ technical personnel of the best calibre that can be obtained in the region. Then young scientists and engineers required in various countries composing the region can get well trained.

Active participation in International Science and Engineering Conferences will greatly benefit the personnel to come in contact with the latest knowledge of the subject.

The problems in the developing countries are different in the present initial stages. In the development of large industrialised nations, basic research in new and active fields of research is necessary. We may call these the front line research. But in developing countries, with immense problems and limited finances, the pattern of research will have to be different. Thus, in India, the increased efficiency of the cycle or improved methods of economic road formation to withstand the use of the bullock cart are of immediate importance while such problems do not mean anything

to advanced countries like the USA. The problems dealt with, must meet the economic and industrial needs of the country prevailing at the time.

(v) The application of Science and Technology is so vital to developing countries that the initiative and effort should start at the highest level in governments. This can only be done by establishing Ministries exclusively for Science and Technology. These should be responsible for intensive and extensive drives in research as well as education in these fields.

If the Ministry has to achieve its full potential, our Governments must adjust themselves to the needs of the times. We should place at the head of the Ministry proved men of science, who command both vision and missionary zeal. Technical men and specialists should be placed in positions of responsibility where they can be more effective than mere officers. A perusal of the proceedings of the British Association for the Advancement of Science of the 80's of the last century show that in under-developed countries the same prejudices prevail today, the scientists suffer from the same handicaps and are pleading for patronage of science in the interest of the State in exactly the same manner as the British scientists did 75 years ago in Britain. They stressed the importance of science and called for an exclusive Ministry of Science, and argued the case for larger funds and separate institutes for research outside universities. And we know now how those countries advanced by accepting the advice of men of vision and foresight. Let us remember that engineers like Watt and Stephenson have contributed more to the prosperity of England than the battles won by her soldiers or treaties concluded by her diplomats. If we would therefore learn from history, from the long experience of the developed countries, we should wholeheartedly use the powerful oars of science to heave our economies to the visible shores of self-sufficiency, which is indeed the end of the beginning for the economic growth of emerging countries, of which we all dream and towards which we are all striving.

Ladies and Gentlemen, I am happy and feel privileged to be the Chief Guest at this Annual Session of the Ceylon Association for the Advancement of Science.

POPULAR LECTURE

(21st November, 1963)

TISSUE CULTURE

By

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To be able to keep the tissues of the body alive in isolation from the rest of the body must have been the dream of biologists and surgeons almost from time immemorial, but nevertheless the practice, science, or perhaps the art of tissue culture is essentially a child of the twentieth century though it was conceived some years before the turn of the century. Roux (1885), Loeb (1897, 1902) and Ljunggren in 1898, for example, had all concerned themselves with trying to keep animal tissues alive outside the organism or under artificial conditions, and had met with some degree of success.

The honours of initiating the method in its present form are, however, usually accorded to Ross G. Harrison of Johns Hopkins Hospital—perhaps because it was he who in 1906-7 first succeeded in producing a result of great physiological, anatomical and indeed biological importance solely by the use of his tissue-culture technique. His experiments were, by present day standards, simple; bnt their results demonstrated the truth of the neurone theory that nerves originate as outgrowths of separate nerve cells. By cultivating amphibian spinal cord in a hanging-drop preparation of frog's lymph in a hollow-ground microscope slide he demonstrated that nerve fibres grow out as pseudopodial processes of the neurones or cell bodies in the neural tissue. He and his contemporaries also showed the capacity of these outgrowths to regenerate from the nerve cell when the peripheral parts were damaged. This was the first major success of the tissue-culture method and the hanging-crop technique was immediately established as a worth-while experimental method for studying cytological problems. The essential requirements were asepsis and a physiological medium. i.e. a medium compatible with biological activity.

Harrison's success with cold-blooded tissues was quickly followed by that of Burrows (1910) who saw that warm-blooded tissues could be readily obtained aseptically and in an extremely active form from chicken embryos of several days incubation. He also made good use of the fact that fowl plasma, unlike that from

mammals, does not clot spontaneously if drawn into non-wettable vessels and quickly cooled. It does clot, however, when warmed and in contact with tissues, so that it readily provides a satisfactory and almost natural supporting medium. For this reason fowl plasma has remained part of the stock-in-trade of the tissue-culture industry since the days of Burrows and is still in demand for numerous purposes, although its high place has in recent years been usurped by media of more defined composition which give the experimenter more control over his variables. Indeed it was not very long after Burrows made his initial experiments that Lewis perceived the enormous advantages of the method for the study of the cytological characteristics of cells. He realised the desirability of using a medium less fickle and unpredictable than plasma. He and Margaret Lewis initiated the use of simple saline solutions (Ringer-Locke), fortified with glucose and chick bouillon as a source of food material for tissue cultures in hanging drops.

Not only was the origin of nerve fibres a burning question amongst anatomists at the turn of the century, but the origin of the heart beat, myogenic or neurogenic, was equally controversial to the physiologists of the time. Once again, tissue-culture provided the solution. Burrows and, somewhat later, the Lewises showed that, in culture, isolated heart muscle cells are capable of rhythmic and independent contraction. Clearly these contractions are myogenic and originate in the muscle itself, and the only doubt remained as to whether the conditions of tissue-culture are sufficiently normal for this result to be considered applicable to cardiac tissues in the body. By 1912 therefore tissue-culture methods had provided the answers to two fundamental biological questions.

Only two years later, in 1914, another mystery was solved by tissue-culture. The Lewises demonstrated by vital staining and subsequent fixation that mitochondria existed in living cells and were not artefacts of fixation as some cytologists had supposed.

Perhaps, however, the observation in the tissue-culture field which really captured the imagination of the world and which directed the course of research in cytology for many years was that of Carrel (1910), who working with Burrows at the Rockefeller Institute in New York showed that a saline extract of embryonic tissues, either alone or when added to the plasma medium of tissue cultures, would greatly accelerate the growth of many tissues and bring about numerous cell divisions. It is not difficult to understand that the discovery of such an apparent growth stimulant should have, wide popular appeal and at the same time focus attention on tissue culture as a powerful tool for the investigation of normal and abnormal growth, and thus as a new weapon in the fight against cancer.

Perhaps part of the conspicuous success of these workers at the Rockefeller Institute was due to their mastery of asepsis. Carrel, by profession a surgeon, was a stickler for meticulous sterilisation; he organised his laboratory on the strictest lines prescribed at that time for operating theatres, with every attention to pomp and ceremony. Indeed the twin appeal of Cancer Research and operating theatre glamour acted as a great advertisement for the method; but it also had its adverse effects. It appealed to the sensational rather than the sound, and it diverted thoughts along the somewhat narrow channels of growth and cancer, and by wrapping up the method in mystical gowns, masks, and black drapery produced an unhealthy atmosphere of mystery and witchcraft in which the whole technique became enveloped.

Whereas this upsurge was taking place mostly in America, there was also great activity in France. Champy was busy studying the growth of cultures along similar lines, investigating in particular the differentiation and apparent dedifferentiation or simplification of cells as they grew out from the original explants. This demonstration of dedifferentiation of histological form posed many problems for these early pioneers and it is probably fair to say that many of the same problems still remain to be solved. Champy's results, from which he drew somewhat gloomy conclusions, certainly kindled a flame, and whereas the American fire licked at the problem of uncontrolled growth, except perhaps in the field where the Lewises were at work, the French flame began to illuminate the dark places in the area of cell differentiation where cells could establish and maintain their physiological functions. In England too, Thomson (1914) called attention for the first time to the events occurring within the tissue explant rather than in the outgrowth. These he saw and recognised to be reflecting the life of cells and tissue *in vivo* much more accurately than the events in the outgrowth from the explant. It was not, however, until ten years later that this great truth was to receive the attention which it deserved.

In the years immediately before the first world war there flashed across the field of tissue-culture in France a brilliant meteor which unfortunately disappeared almost equally suddenly. The name of the meteor was Levaditi. It was he who in 1913 pioneered the investigations that led to the award of a Nobel Prize some forty years later but to another investigator. It was Levaditi who began the culture of poliomyelitis virus in tissue cultures. He cultured it in the nerve cells of monkeys. Not only did Levaditi attack this and other problems in the growth of viruses but within the space of about two years he was also investigating the action of ultraviolet light, X-rays, and radium on cells *in vitro*; he extended the study of toxins *in vitro* which Lambert and Hanes had initiated

a year or two earlier and he became involved in the study of the immunity reactions of cells. Not satisfied with this he and his colleagues Comandon and Jolly took cinematograph films of beating heart muscle which were certainly among the first to be taken of cells in culture, though Braus in Austria was also doing something similar in 1912.

This golden-age of tissue-culture, like that of certain other aspects of human culture which occurred from 1910-1914, was destined to come to a sudden and inglorious end with the beginning of the first World War. However, in the next five years, although there were no developments in the field of tissue-culture of comparable appeal to those of the preceding five years, these years were not without their significance for the future of tissue-culture. Several researches which have had far-reaching results were quietly inaugurated during that period. For example, the foundations of the techniques of microdissection, microinjection, and microstimulation and recording were being laid by the capable hands of Chambers, though his methods were not directly applied to tissue-culture until much later, when Chambers met Strangeways in Cambridge. In 1915, Baitsell, perhaps stimulated by the needs of the soldiers mutilated in the war, began the study of wound repair at the cellular level and particularly of the function of connective-tissue fibres, a problem which still has many unsolved features in spite of intensive study with modern biochemical, biophysical and electron-microscopical methods which were unheard of at the time of Baitsell's original investigations.

In 1916 Rous and Jones used trypsin to digest the plasma clot of tissue cultures in order to liberate the cells from this very efficacious tissue-culture medium, and they found that the cells so liberated could be freely suspended in fresh medium and were still viable and capable of further growth. This discovery, which passed almost unnoticed at the time was later to become of enormous importance in the development of the methods for the massive cultures of cells which are so extensively used in biochemical research, in the growth of viruses, and to a less extent in the study of differentiation. Present-day methods for the cultivation of viruses thus had their origin in work first published in 1913 and 1916.

When peace returned to the world in 1919 the glamour of tissue-culture caught the popular imagination. The artificial stimulation of growth with its immediate application to the problem of cancer, the apparent immortality of cells in culture, the black hoods and gowns of the tissue-culture devotees in the Rockefeller Institute, and, not least, the shear beauty of cells growing in culture, attracted attention and made it appear that the riddle of cancer would be solved in the near future; even immortality seemed, to the optimistic, to be just round the corner. 'Cancer Research' flourished and funds in its support grew rapidly so that it was almost true to say that Cancer began to keep more research workers alive than it killed those who suffered from the disease. One investigator after another climbed on to the band-waggon and, in consequence, much superficial, trivial and even poor work resulted and tended to swamp the more fundamental work which, of course, was still steadily progressing. Tissue-culture got a bad name.

While, before the first war, most of the work on tissue-culture was being done in America, though Champy had a nucleus of activity in France, and there were isolated pockets elsewhere, after the war the fever spread far and wide. Fischer, who had worked with Carrel and Ebeling at the Rockefeller Institute in New York set up a very vigorous institute in Copenhagen. Levi, in Italy applied himself to the study of cell behaviour *in vitro* and began to exert a wide influence throughout Europe.

In England, Strangeways, moved by an insatiable desire to understand the diseases with which he, as a pathologist, came in contact, established a research hospital, primarily for the study of rheumatoid and arthritic diseases. He very early applied the methods of tissue-culture to this problem, and did so to such good effect that, after a financially very precarious start and greatly relying on goodwill and voluntary effort, the hospital became a laboratory and, in due course, a primary centre for the study of the growth of bone and cartilage, mostly by tissue-culture methods. Just as the American school saw tissue-culture as the key to the understanding of growth, Strangeways and probably the majority of Europeans became more fascinated with the method as a means of unravelling the processes of differentiation and cellular function. From the practical point of view it is worth noting that at this time, in the early twenties, dark-field illumination was only just beginning to widen the horizon of high-power microscopic studies. Phase-contrast microscopes and electron-microscopes were still in the distant future. There were no such things as anti-biotics. Thus the available methods were, by modern standards, extremely primitive.

These were the days when experimental embryology was rapidly developing under the influence of such figures as the elder Brachet, Morgan, Spemann, Mangold and others and it may be that the concept of one cell group influencing another in the course of embryonic development was one of the dominant ideas running through cellular biology at the time. Champy, for example, as early as 1914, had called attention to the beneficial influence which mesenchymal tissues had on the differentiation of epithelia, an

observation which was repeated by Drew in 1923 and which in essence has been amply confirmed by more recent work. Champy himself was convinced that cells in tissue-culture more or less quickly dedifferentiate to an indifferent type, and he was much influenced by this concept of dedifferentiation. There was certainly much truth in his ideas, though subsequent work has shown them to be erroneous in several important respects. Nevertheless it is certainly true that there are many cell strains, now in cultivation, which though theoretically derived from different sources, show a remarkable uniformity of apparently identical and dedifferentiated cells. Dedifferentiation, however, does not necessarily mean simply reversing the process of differentiation and the return to a primitive condition. Adaptation to the simpler conditions of tissue-culture is a potent influence.

With this background of the early history of tissue-culture and of how the stage was set for its development after the first World War, it may now be of interest to review a few of the main contributions which the method has recently been making, and to try to assess the value of the method at the present time, and, tentatively, to predict its future.

Perhaps the most important new concepts which have emerged within recent years from the field of tissue-culture are those that follow from the clear recognition of the differences between organ cultures on the one hand and cell cultures on the other. Tissue-culture, as such, i.e. the explanation of tissue fragments and the study of the emigrating cells, is seldom practised today. In organ cultures everything possible is done to keep the cells in their natural environments and with their normal relationships with their neighbours, and with the intercellular ground-substances and basement membranes. The polarities of the cells with respect to any surfaces with which they may normally be in contact are respected and, if possible, preserved. In cell cultures, on the other hand, the aim is to obtain as uniform a population of cells as possible so that they can be subjected to a known and uniform environment and so that their biochemical and biophysical properties may be determined in relation to that environment. The goal, in both cases, is a completely synthetic environment of known composition, a goal which it need hardly be said is almost, if not quite, unattainable since the cells themselves start to contribute to that environment as soon as they are placed within it. In order to obtain, for cell cutures, as uniform a population of cells as possible it is preferable to initiate the culture from a single cell i.e. to start a clone. This simple idea, however, immediately raises many practical difficulties, not the least of which concerns the identification of the original or founder cell. It is obvious that unless this identification is absolutely certain, the findings may be valueless. Moreover normal cellular activity, as organ culture clearly shows, often depends on the interaction between cells of different types; thus the uniform cells of a clone may be be-having in their own peculiar way which has no relevance to the normal activity of the cell from which the clone was derived. Thus measurements of their metabolism, though relatively easy to make, may be quite meaningless, and it is necessary to treat such measurements with the greatest caution.

For many years it was impossible to clone fibroblasts: isolated cells always perished. However, in 1948, Sanford, Earle and Likely at last succeeded; they first isolated the cells into extremely fine capillary tubes in a growing culture. They then cut the capillary tubes into lengths each containing only one cell. These tubes were planted into a medium which had previously supported a colony of fibroblasts and was therefore 'conditioned', but not exhausted. The isolated cells then multiplied and produced colonies which invaded the medium. Later, Puck succeeded in establishing colonies of fibroblasts by plating them out on to layers of cells whose multiplication had been stopped by X-rays but which were still alive and metabolically active and which thus acted as 'feeder' cells. Still more recently, with improved media and techniques even the feeder layer has been found unnecessary. Undoubtedly one of the main obstacles to be overcome in this type of culture is to prevent the loss from the cells of essential constituents by diffusion into the medium. A cell may be able to synthesise limited quantities of certain necessary metabolites, but, if these metabolites diffuse away into a relatively large volume of medium more quickly than the cell can make them, the cell may be exhausted before the medium is saturated and the necessary concentration in the cell maintained. The addition of extra amounts of these substances to the medium may sometimes be able to restore the balance and prevent further loss, but questions of directional permeability of the cell membranes are involved. In nearly all cases beneficial results accrue from the addition of serum, even in low concentrations, to an otherwise partly synthetic medium; certain of the serum proteins are at least partly responsible for this beneficial effect. Cells with epithelial characteristics may also be able to initiate clones in this way and such clones are morphologically distinguishable from clones with fibroblast—like characteristics; in general, however, there is an extraordinary similarity in biochemical properties between the various races of cells which have been so far investigated in this way and it seems fairly safe to conclude that such cells growing freely in contact with the medium can adapt themselves to life in these simplified conditions and eventually develop, sooner or later, into what can only described as 'tissue-

culture-cells'. Such strains of cells are useful and almost ideal for studying such general metabolic features as are probably shared by most animal cells and are concerned with growth, reproduction, protein synthesis and the like. On the other hand those metabolic features which are associated with special functions cannot, in general, be investigated on these strains.

Strains of this type are usually maintained in dishes or in flat flasks and are grown in controlled gas mixtures, e.g. 5% CO_2 in air. At one time it was thought that, for growth and multiplication, it was necessary for the cells to spread out on a surface and be able to move about. This apparently is not always so, for several strains of cells have now been kept growing in agitated fluid media in which the cells attain very considerable densities of population, i.e. several million cells per ml. For stabilising such cultures serum may be necessary, although in some cases methylcellulose can act as an efficient substitute. Such cultures have the enormous advantage of easing the biochemical investigations on the cell metabolism by providing greater amounts of material, but, as already stressed, they have the disadvantage that the cells have largely lost any individuality which they may have had before they were cultured. Furthermore Earle has reported that of two clones started from the daughters of a single cell division each behaved quite differently; one became malignant, the other not. Nevertheless these massive cultures of cells fulfilled the wishes and dreams of many of the early tissue-culturists and, though the uses to which they can be put are probably not exactly those for which they were designed, they certainly constitute a technical triumph and open up many new-possibilities for research. In 1922, three or four small pieces of tissue could be grown in about 2 ml. of medium in a small flat Carrel Flask. The medium was usually composed of adult fowl plasma and chick embryo tissue extract. It is difficult to imagine a medium of greater complexity and unpredictability. In 1962, litres of cell suspensions, with a million cells per ml., could be prepared in media which for one or two cell strains at least are initially entirely chemically-defined so that any changes which are recorded in the medium can be attributed to the cells. Such mass cultures are not only of the greatest interest to biochemists but they also provide ready culture media for viruses.

Cell strains grown in flat dishes form a ready means of counting virus particles, since the latter often produce centres of necrosis or of visible change in the cells. They can also be used to study the intimate action of the virus on the cells. Sometimes, as by Polioma virus, the cells may be very much transformed. Measles infected cultures in certain media becomes rich in giant cells.

On a more modest scale than these massive cultures, suspensions of embryonic cells, carefully prepared with the help of various dispersive agents are being used to investigate the inter-relationships between cells, the mutual contacts and adhesions which they make. The dispersive agents used for making such suspensions are such digestive enzymes as trypsin, elastase, mucinase, collagenase etc., and these may be combined with Ca^{++} and Mg^{++} free solutions, of different total salt concentration and pH. Such solutions may also contain such inert molecules as methyl cellulose, sucrose or ion-binding agents like versene. The dispersed cells are then encouraged to aggregate together by controlled agitation of the suspensions and the cells are found to sort themselves out in a definite hierarchy of adhesiveness and to rebuild new 'organisms' in which the cell differentiate. Thus the original observation of Rous and Jones in 1916 that trypsin could disperse cells and do very little damage to them has come to fruition both in the production of enough cells for mass biochemical studies, and also in the more intimate study of cell aggregation and differentiation.

Apart from these two very important lines of investigation with isolated and dispersed cells, the other main interest of tissue-culture since the second World War has shifted to the problem of preserving cells in their functional and differentiated condition and to the investigation of the actions of humoral agents on their differentiation or their physiological activities, and this is the branch of the subject which has become known as organ culture.

The methods had their first origins with Roux in 1885 and A. Brachet in 1913 who cultured mammalian blastocysts in tubes of plasma. It has already been mentioned that in 1914 Thomson called attention to the events which were occurring within the central explants of organ rudiments growing in a tube and really initiated organ culture as such.

Maximov, in 1925, made cultures of mammalian embryo by somewhat similar methods, but it was not till the late 'twenties' that it was shown that organ rudiments would go on developing *in vitro* in a surprisingly normal way. Eyes for example, though they might be anatomically distorted could remain essentially normal at the cellular level. A limb-rudiment would develop cartilage and bone and even produce the basis for joints, though the latter would not become functional and eventually retrogressed, probably for lack of muscular activity and the mechanical forces normally exerted by contracting muscles.

The histological normality of the cells in these organ cultures is remarkable. In modern methods, the tissue is generally suspended on a floating raft of rayon or on a metallic grid at the interface between a nutrient medium, which may be completely synthetic, and a gas phase which may be 5% CO_2 in air, or occasionally in oxygen. In this situation small pieces of either embryonic or adult tissue, of generally less than 2 or 3 mm square, depending on the tissue, can remain surprisingly healthy for many days, and small pieces from adult organs can survive almost as readily as whole organs from embryos. Moreover, the cells in these explants react to external stimuli applied to them. Perhaps the most interesting and illustrative example of how this sort of method is being put into action concerns the mode of action of vitamin A. The problem started with observations on paralytic puppies, but it has had repercussions on the formation and destruction of bone and cartilage, on the differentiation of epithelia, and at present it is centred on the structure and permeability of cell membranes. In all these investigations tissue culture has played a dominant role. Dogs on a diet restricted in its vitamin A content and high in cereals were observed by the late Sir Edward Mellanby often to become deaf and to develop various signs of neural degeneration and paralysis. On further examination, Mellanby found that the effects were probably not primarily due to neural failure, but they were caused by a failure of the animal to remodel its bones as it increased in size so that the neural tissues were progressively compressed, and their blood supply interfered with, so that they ultimately were caused to degenerate. The primary failure was therefore in the bone. This was where organ culture stepped in. Mellanby enlisted the help of Miss Fell—now Dame Honor Fell, who subjected embryonic bone rudiments in organ culture to high (physiologically speaking) concentrations of vitamin A. These cultures produced the remarkable result that the matrix of the cartilage, and in some cases of the bone began to disappear, and the bone rudiment could be reduced to a mass of fibroblast-like cells. It has since been shown that this lysis of the matrix is probably caused by proteolytic enzymes, and there is evidence that vitamin A assists in their liberation from certain intracellular granules or lysosomes in the cells. This, however, is not the whole story. When pieces of chick skin were grown in organ culture in media containing high vitamin A, the epithelium was found to change from being stratified and feather-producing to become a membrane provided with goblet cells and cilia, just like the mucous membranes of the respiratory passages. The epithelium of the old type was sloughed off, and from its basal cells there grew up the cells of the new types. It is, however, not yet known how far this is a direct effect of vitamin A on the epithelial cells, and we already have the warning that the effects of A—deficiency on the nervous system of dogs were probably not in any sense primary. Moreover, Dr. McLoughlin has recently shown that, if a piece of epithelium from the skin of a chick is detached from its underlying connective tissues and organ-cultured on connective tissue from the stomach or intestine it develops not into a feather producing epidermis as it does if grafted back on to its own type of connective tissue but into a glandular epithelium more in keeping with its new situation—the underlying connective tissue is clearly exerting some influence on its differentiation, just as has been shown by Gorbstein in California to happen when salivary gland and kidney rudiments are grown in contact with their own or with other mesenchymal elements.

Enough has probably been said to illustrate the great suitability of these newer techniques of organ culture for the study of the interaction of various tissues, and for the analysis of the effects of vitamins or hormones on tissue organisation. As examples of the action of hormones on cells in culture that of progesterone on the cells of the vagina is very comparable with that of vitamin A on the skin. Testosterone induces changes in the secretory epithelium of the prostate gland in cultures and many other hormones have been shown to affect the behaviour of cells in organ cultures, although they may be apparently without effect on the cells in the outgrowth of tissue cultures or on cell cultures. Clearly the comparatively normal organisation of the cells in the tissues of organ cultures is a cardinal feature in relation to their more physiological functions. Of topical interest are the changes which extracts of cigarette smoke produce in respiratory epithelia. In short, organ culture is destined to play a dominant role in the endocrinology and toxicology of the future. Only by its use can the direct actions of hormones on cells and tissues be satisfactorily investigated. The more physiological the medium and the more normal the cellular arrangement the more reliable must the effects become and if the medium can be chemically-defined, so much the better. Nevertheless, it is necessary always to bear in mind that tissues *in vitro* are seldom, if ever, quite normal and, in consequence, the results have to be interpreted with caution.

The effects of vitamin A on cells seemed, as has been said, to be at least partly explicable in terms of the liberation of proteolytic enzymes from the intracellular lysosomes. Further investigation with vitamin A carried out at the Strangeways Laboratory in Cambridge have indicated that these effects are likely to be due to the action of the vitamin on the lipid membranes in the cells. For example, the vitamin has been shown to be capable of causing the lysis of red blood cells and interest is now centring on the molecular nature and the ultra-microscopic structure of such membranes and those of lysosomes in a search for the possible ways in which the vitamin could interact with them. Here again cells *in vitro* provide excellent reference material.

Now, what of the future? The days of blood and thunder physiology are over; the boiling vats of the early biochemists have cooled. Cells and subcellular particles interest physiologists and biochemists alike. Delicate chromatographic and electrophoretic methods allow separations, identifications and measurements undreamed of by the founders of tissue-culture. As better methods for investigating normal cellular activity of the kind already in use in tissue-culture are devised and perfected, so biochemistry and biophysics will proceed actively and rapidly on a sound basis. Team work will become more and more necessary; the demands on the individual for the mastery of all the technical skills required are such that few could succeed alone. Moreover, it is often advantageous to record many kinds of observations simultaneously. The actions of hormones, of vitamins, and of many drugs will, I believe, be elucidated most easily and most soundly with the help of some form of cell or organ culture, probably the latter. In embryology, developmental forces can be the subject of ready experimentation by culture methods. Tissue-culture in virus research has a secure place, and the main features of malignant disease are obviously best investigated at the cellular level, and here I would stress the need for studying the inter-relationships of the cells and their intercellular matrices as well as the factors which control cell multiplication. In neurology, nerve cells and neuroglia can be persuaded to reorganise themselves in living cultures in a manner accessible to direct observation and experimentation. Even genetics now uses culture methods for determining the chromosome patterns associated with hereditary diseases, and here lies the place for the study of the interaction between the nuclear constituents and the cytoplasmic constituents both in growing cells and in functional cells.

Tissue culture has much to contribute to the future of biochemistry, physiology, endocrinology, embryology, pharmacology, pathology and genetics, but it requires both common sense and uncommon patienee.

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