CEYLON ASSOCIATION

FOR THE

ADVANCEMENT OF SCIENCE

PART II

PROCEEDINGS

OF THE

TWENTYSECOND ANNUAL SESSION

14th to 17th December 1966

COLOMBO 1967

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The Ceylon Association for the Advancement of Science
14th December, 1966

Inaugural Address

by

HON. J. R. JAYEWARDENE
MINISTER OF STATE

Mr. President, Ladies & Gentlemen,

I consider it a great honour to be associated with the Twentysecond Annual Session of the Ceylon Association for the Advancement of Science. It was 18 years ago, in 1948, that I was accorded a similar honour by your Association, when I opened your 4th Annual Session. Since then several world famous scientists have been your guests and delivered important and learned lectures, and the activities of the members of your Association have covered every aspect of scientific knowledge. Your annual reports, some of which I have been able to read, show the diverse nature of your membership, and the variety of subjects that are studied and discussed by these members.

During these 18 years, in certain spheres, scientific research and discovery have achieved results which will change the course of human progress, as did in its time, the discovery of the use of fire or the wheel, in the early life of man on this planet; or the use of steam and electrical power in more recent ages. The consequences arising from man's ability to use nuclear power, his ability to travel beyond the earth's gravitational pull, open up fields of adventure and discovery, without limit. I will not venture to dwell longer on these subjects which are more appropriate for discussion by those specially qualified to deal with them.

Though there are different spheres of scientific study, science has a common method and approach to the subjects under its review. The scientific approach always seeks to gain and verify knowledge by exact observation and correct thinking. This approach does not and cannot stand for narrow national or racial divisions; it stands for humanism, for tolerance, and for reason. The scientific approach is essentially a search for truth, wherever the truth may be found, and its conclusions have always helped the onward march of the human race.

In our country too, science has helped us to progress in several fields of human endeavour. When I addressed you last in 1948, the year we regained our freedom, our people had great expectations and high hopes. When we look back in retrospect over these 18 years, not in one sphere alone, but over the whole gamut of life in this country, we find a record of achievements in some and failure in others. Science has helped us to increase our production of essential food. It has shown us methods for increasing the yield of our chief export commodities so that we may compete in the markets of the World. Industrial development is taking place slowly and surely. Yet the rate of growth of our population exceeds the rate of growth of our material resources so that, in very broad terms, the per capita wealth of our people has not kept pace with similar progress among the peoples of the developed nations of the world.

In order to secure the help and advice of men learned in science, the Government is preparing legislation to set up a National Science Council and an Atomic Energy Authority. The former will be the official body that will advise the Government on matters relating to science and technology. It will also have functions connected with the promotion of scientific research and education. The latter Authority will be responsible for the country's development in the field of nuclear energy. Legislation concerning the mining and refining of Radio-Active Minerals in Ceylon is also being finalised.

The failure to provide material comforts, in which phrase I include lower cost of living, employment, housing facilities, and adequate leisure, make people blame those who are in charge of the machinery of Government at a given time. The politicians in power are the target of criticism. It is argued that the politicians in power know what is wrong in the economy, they are aware of the remedy, but the desire to be popular and to secure a majority of votes at a general election prevents them from taking the correct remedial measures. They in turn blame the system of government. It should, however, be remembered that among the new emerging nations in the continents of Africa and Asia, only two countries,

India and Ceylon, have preserved the democratic system of Government intact; and of these two, it is only in Ceylon that the people have been able to replace one government with another, without violence and purely by the use of the vote; not on one occasion alone, but on four occasions, during these 18 years.

A democratic system of Government includes what are termed "democratic freedoms", the freedom to vote, freedom of opposition, freedom of speech and writing, and the rule of law, among other freedoms. Do these freedoms alone satisfy the people? I do not think so. They need material comforts too. While counting the preservation of democratic freedoms as one of our achievements since Independence, we have not achieved the economic freedom that our people are entitled to. This has been one of our major failures.

If then the system of democratic government has failed in some aspects, we should not hesitate to think of changes and amendments in that system where necessary. Parliament intends to examine the whole system of democratic government in our country, and while maintaining the basic freedoms of democracy, which in my opinion have not failed and need no change, adopt such reforms as would help the nation to solve its problems effectively and expeditiously.

Universal franchise and the free exercise of the vote are necessary pre-requisites of democracy. However, the electoral system which prevails here today, where the elector elects his legislator according to defined electoral areas, is not necessarily the best for our country. In some democratic countries political parties put forward a list of the names of candidates seeking election; the legislators are then chosen from this list; the number depending on the votes cast for each party. There are no electorates. The voter votes for the Party and not for a particular candidate. Today's electoral system in our country precludes the best equipped men and women from taking part in our political life.

Our Cabinet, the executive government, is chosen from the Legislature and throughout its life is dependent on its maintaining a majority therein. We have followed the British Constitution in this respect. In some countries, the Executive is chosen directly by the people and is not dependent on the Legislature during the period of its existence, for a specified number of years. The U.S.A. is an example of the latter. The new French Constitution is a combination of the British and the American system. Such an executive is a strong executive, seated in power for a fixed number of years, not subject to the whims and fancies of an elected legislature; not afraid to take correct but unpopular decisions because of censure from its parliamentary party. This seems to me a very necessary requirement in a developing country faced with grave problems such as we are faced with today.

Again, the full period of life of an elected parliament in our country is 5 years. After a general election, for one year a new government celebrates its victory and in settling down; the last two years before the general election are devoted to how to win the election that is to come; the period during which new measures can be adopted and implemented hardly exceeds two years. In England at one time the period was 7 years. This period of 5 years also needs consideration.

The functioning of Parliament itself in this country has been a good example of the proper use of democratic freedoms. The opportunity for free debate, the presence of Ministers in the House and their being subject to questioning and censure, the free play allowed for all shades of opinion to operate within the parliamentary democratic system, I think, are valuable freedoms, and prevent the growth of tyranny and oppression. A Government which has nothing to hide need not fear to face Parliament at anytime. The Parliamentary Forum, the Independence of our Judiciary, and the application of the Rule of Law stand out as features of the democratic system that need to be zealously preserved.

I am advocating a scientific approach to the study of some of our political questions. Such an approach must necessarily mean the abandonment of race and religious intolerance. It encourages equal opportunities for all citizens. Just as scientists applying the methods of scientific approach keep the light of reason burning, so too should the politician fashion a democratic form of government that will help him to keep to the right path, even when passion convulses the multitude. The new forces that man uses today did not come from outside the World, from Space, but lay hidden within the womb of knowledge, awaiting discovery; so too in the democratic system of Government, there are solutions to the problems of government that face us today. We need not seek abroad. Let us turn the search light inwards; we will find within the problems themselves the solutions we need. The devotee of science in the pursuit of knowledge does not stray from his ideals. He follows right, for right is right, without fear of consequence. The politician in the pursuit of happiness for those whom he represents need only follow this noble example.

General President's Address
14th December, 1966

THE ROLE OF ENERGY IN DEVELOPMENT

by

V. APPAPILLAI

Hon. the Minister of State, Prof. Powell, Hon. Ministers,

Your Excellencies, Our Distinguished Guests, Friends and Colleagues:

I wish to express my deep appreciation of the honour the Association has done me by electing me its General President for this year. Conscious of the responsibility the Association has placed in me and my colleagues on the Council, we have got through a programme of work detials of which are given in our Annual Report. My task has been rendered light through the willing co-operation of the Members of the Council, the energetic General Secretaries, the Treasurer and the Editor. To them I express my sincere gratitude.

I have called this address 'The Role of Energy in Development', because in it I want to trace the key role energy has played in bringing about social transformations through the ages and also make some suggestions for the development of our own society.

The growth of man's dominion over matter through his ability to control energy has been a long-drawn-out process. It began with the dawn of human history and is still continuing. Conscious systematic investigations into the relationship between matter and energy had their beginnings only a few hundred years ago. Nevertheless, within this short interval of time, much less than one per cent of the period of human existence, progress in control of energy has led to vast transformation in the patterns of society.

Mainly through fast and cheap transportation, distances have been shortened at an astonishing rate. Societies which for thousands of years lived in isolation, ignoring one another, have been suddenly put together. Through their mutual interactions and evolution, the nations of the world of today have become divided into two groups—the rich and the poor or in the parlance of the day the 'developed' and the 'under-developed'. The rich nations constituting less than one-third of the human population produce and consume more than two-thirds of the world's good and their out-put is increasing faster than their populations. On the other hand, the poor nations are still occupied with thier subsistence agriculture and are faced with the problems of over-population, unemployment, under-employment and even starvation. The material prosperity of one group of nations and the poverty of the other stem from the fact that the rich nations have harnessed all forms of energy for their productive enterprises, whereas the poor nations have not as yet fully mobilized even the energies of their own people.

In our own country exploitation of energy for productive purposes has not kept pace with growth of population, with the result that we are confronted with all the problems of an under-developed nation: our population of 12 million people is more than we can support on our present resources and it is increasing at an explosive rate; unemployment and under-employment are widespread in the country and on the basis of current achievements, even the present standard of living does not seem to be assured for the future. In a situation like this it is very necessary that we should make a survey of the growth of control of energy by man and take note of the lessons that history has to teach us.

2. SOURCES OF ENERGY

All forms of mechanical energy that man has so far put to practical use may be broadly classified into two groups, namely (*a*) animate energy and (*b*) inanimate energy. Animate energy of muscular action of men and animals is derived from the food they eat. Inanimate energy may be derived from (*a*) wind and water, (*b*) chemicals like gunpowder or fossil fuels like coal, oil and natural gas and (*c*) nuclei of atoms.

Man is the most important prime mover and the food he uses as fuel deserves special consideration. Food provides man with the necessary energy to keep him alive and active. The ultimate source of all food is the plant. Recent developments in biology have shown that plants and animals behave in certain respects like heat engines and are, in a broad sense, subject to the laws of thermodynamics. The first of these laws, as you may recall, states that energy may be transformed from one form to another, but can neither be created nor destroyed. The second law states that no process involving an energy transformation will occur, unless there is a degradation of energy from a concentrated form into a

dispersed form. A plant absorbs energy in the form of sunlight—the concentrated form—and through the process of photosynthesis converts a portion of this energy into chemical energy of food. It rejects the remaining energy in the dispersed or unavailable form. It is clear therefore that the energy of all food comes from the sun and that the plant acts merely as a converter of solar energy into energy of food. It is important to realize that the plant is the only known organism that converts solar energy directly into energy of food. A rough estimate indicates that a square metre of cultivated land can trap and store about 5000 kilo-calories of solar energy per year.

So long as the flow of solar energy into a given area of land is limited, the only way to increase food production under ideal conditions of growth is to increase the efficiency of conversion by the plant. This is the fundamental reason for the selective breeding of plants.

What is left of the plant as unsuitable for human consumption may yet be used to feed edible animals. So edible animals can also be called converters. These animal converters transform about 10 per cent of the energy they consume in the form of food into meat. It will be seen that to produce the same number of calories in the form of food, animals require ten times as much land as plants. This is the chief reason for the high cost of food from animals. Selective breeding of animal converters with high genetic potential is also the answer to the problem of high cost of such food.

Let us now consider the out-put of mechanical energy by man regarded as a heat engine or a prime mover. A healthy workman needs about 2500 kilo-calories per day in the form of food. Most of this energy is used up in the body functions needed to keep him alive. On the average only about 10 to 20 per cent of this energy becomes available for muscular activity. With proper periods of rest and relaxation, a workman is capable of doing sustained work at the rate of 1/20 to 1/10 horsepower for 8 to 10 hours per day. At the rate of 2000 hours of actual work for the year, the energy out-put of man, the prime mover, turns out to be about 100 kilo-watt-hour per year. We get an immediate idea of the value of this work in terms of money, if we realize that it costs only about 15 rupees to take this work off the electric mains supply. On the other hand, the social progress we have made is such that we cannot find a labourer who will work for less than 1000 rupees per year. This high cost of human labour seems to suggest that it would be unprofitable to use such labour if human skill and adaptability are not absolutely essential to the task.

Draught animals specially bred for the purpose are useful where heavy labour is involved. A familiar example is the use of buffaloes to plough paddy fields. Here again unless the working conditions necessitate the use of these animals, it would be cheaper to use sources of inanimate energy.

3. CONTROL OF ANIMATE ENERGY

Let us now make a brief survey of the various ways in which animate energy has been used in the past. Since authentic records relating to the early history of man are not available, it is necessary to make suitable guesses with regard to this period.

When man emerged in his present form, he found plant and animal converters already in existence. For many thousands of years he spent all his time and energy hunting, fishing and gathering wild fruits for his food. In the course of time he invented and developed new skills such as cutting of stones, making of special weapons and transport devices. These new skills and innovations made him more and more efficient in hunting and fishing, but in no way changed his mode of living.

The more efficient he became, the less was the chance of survival of the plant and animal converters in his neighbourhood. Starvation was a constant threat forcing man to infanticide and cannibalism. Gradually however, man learnt the value of the plant seed and the use of fire. Cultivation of edible plants and the cooking of plant products brought him new sources of energy. Domestication of animals was the next stage of development. With this plentiful supply of food or energy, populations began to expand and community life emerged. This transformation of man from food gatherer to food producer marked the beginning of the Agricultural Revolution which took place nearly ten thousand years ago.

The progress of agriculture quickly exhausted the fertility of the soil. Starvation which was once again a constant threat began to limit the size and stability of the communities. Such limitation obtained to a lesser degree in the valleys of the Indus, the Tigris-Euphrates and the Nile, where the natural flooding of the rivers deposited a fresh layer of silt annually. As a result, more settled communities flourished in these valleys. Drainage of the marshland and the irrigation of the desert led to considerable expansion of the areas under permanent cultivation. With the discovery of the plough the energy of domesticated animals

was harnessed. Plot cultivation changed over to large scale field agriculture. Communities grew in size from villages to towns, and from towns to cities and the population expanded to a level never reached before.

With the surplus production of food, it became possible for certain classes of people to free themselves from the hard labour of food production and devote their energies to other forms of activities. Among these it is worth considering the activities of two classes, namely the priestly scribes and the craftsmen. The priestly scribes were the thinkers of the time and they controlled the organizations of the people and their activities; the craftsmen were engaged in such activities as building of vehicles, ships, mechanical devices and the development of the chemical arts.

The priestly scribes were in the habit of recording those disciplines which they had developed themselves during the course of their duties: mathematics for the purpose of keeping accounts and surveying, astronomy for calendar making and astrological forecasts, and medicine for curing diseases and driving away evil spirits. They rarely recorded a knowledge of the chemical arts, metallurgy, dyeing and so on, which belonged to the tradition of the craftsmen who handed on their experience orally under oaths of secrecy. This rift between the tradition of the priestly class and the tradition of the craftsmen, also perpetuated in later civilizations, has been fatal to the early development of science and technology.

With the spread of civilization, the most advanced thinkers of the time soon realized that if man was to develop his noblest faculties, he had to free himself from all tasks that involved manual work. Two courses of action were open to such men: one was to withdraw from the material world as did the yogis of India, and the other was to compel other men to do more work than they received in return. Both courses of action seem to have been followed: the first inspired spiritual growth and the second led to slavery which was to be brought to an end by the progress of technology.

The exploitation of slave labour coupled with progress in craft techniques ushered in an era of new levels of prosperity for the strong. However, the art of organizing and exploiting the energy of men and animals has had many ups and downs. Whenever a group of men learnt a new way of organizing and controlling animate energy, the group developed ambitions of territorial expansion through the exercise of the military arts. The mobility and striking power of the armies of that time depended very largely on their potential of animal power and transport devices and other creations of craftsmen. It was only in such circumstances, where a common enemy was involved, that the thinker and the craftsman had a common interest which benefited both.

Although there was little contact between the thinkers and craftsmen during normal times, the Greek thinkers had analysed their contemporary machinery into five simple machines. These were the lever, the wheel and axle, the pulley, the wedge and the screw. It was recognised that these five simple machines were playing their part singly or in various combinations in the machines created by the craftsmen. As we know it today, these machines merely help to overcome large forces with small effort, but in no way reduce the work done in any operation. The skill and adaptability found in men was ideally suited to operate these machines and slave labour was extensively used even where heavy work was involved.

The marvellous civilizations of Egypt and Babylon and the amazing modern conveniences the patricians of Rome were able to develop were all founded on the energy of millions of highly trained slaves. In the words of a recent writer, "The civilization of Athens represents one of the loftiest soarings of human genius in the realm of pure reason. This tiny group of men, numbering some 20,000, who succeeded in a few centuries in creating a new climate of life in which logic took precedence over force, and beauty over utility, stands perhaps for the most wonderous miracle of social progress ever achieved. But this miracle would have been impossible without the muscular energy of 400,000 slaves, whose services gave their masters time to think" (Tiraspolsky,). In our own country we still have what remains of the glorious civilizations of the past. Without recourse to history, from energy considerations alone, we must conclude that these achievements were based on the muscular energy of thousands of people who were compelled to work.

4. CONTROL OF INANIMATE ENERGY

The 'dark ages' extending from about the time of the fall of Rome in the 5th century to the first intellectual reawakening of the West in the 10th century are traditionally regarded as a somewhat barren period in the history of European civilization. Although the water-wheel was known during the time of the Romans, it was not much used because of the availability of cheap slave labour. But by the middle ages most villages in Europe had their own mills. The Doomsday Book of 1086, it is said, lists some 5000 mills in England alone, indicating that on the average there was one mill for 400 people. During the next century windmills appeared.

The harnessing of these forms of inanimate energy made it possible to release many people from the crude manual work they were engaged in earlier. Trade, commerce and craft techniques began to flourish rapidly. The growth of trade was accompanied by new navigational discoveries which extended the scope of sea transport and also reduced the labour of galley slaves. The growth of craft techniques soon led to such innovations as the spinning wheel and the loom. Perhaps the most important single application of water power was to the bellows of iron furnaces in the production of cast iron.

Fire-arms based on the inanimate energy of gunpowder first appeared in Europe in the 13th century. The Hundred Years War which followed provided the testing ground for this new instrument of power. With the introduction of fire-arms the days of the armoured knight and his fortified castle came to an end. A spectacular flowering was to be seen in all the arts and the sciences. Gun in hand, Europe set forth to conquer the world. Spain and Portugal, followed by Holland, England and France set sail across the oceans to discover and colonize new lands. The far reaching revolution of this period was founded on many other technical advances besides the use of gunpowder. But quite literally it was the sound of the cannon that awakened Europe and plunged it into the ferment of the Renaissance.

Among the later developments, special mention must be made of the works of Galileo and Newton. Galileo, with tremendous insight began to use what we now call the scientific method to investigate the natural world. Newton, building on the foundations laid by Galileo, showed that heavenly bodies obeyed the same laws as did the earthly projectiles. This was a tremendous blow to the teachings of metaphysics. It is possible to trace directly from this fundamental attack on mechanics, the rapid growth of the control of energy and the achievements of science and technology of the present day.

The philosopher of the scientific revolution was Francis Bacon who in 1605 wrote: 'Men have withdrawn themselves too much from the contemplation of nature, and the observations of experience and have tumbled up and down in their own conceits' and 'it is esteemed a kind of dishonour unto learning to descend to inquiry or meditation upon matters mechanical'.

For two and a half centuries the brilliant advice of Bacon was unheeded both by the statesmen and by most of the academic world to whom it was addressed. Nevertheless, there was a gradual change leading to the convergence of the traditions of the philosopher and the traditions of the craftsmen, resulting eventually in the fusion of the two. The first vacuum pumps were made in 1650 by von Guericke of Magdeburg, stimulated by his curiosity at the failure of his pump to send water to the top floor of his house. Boyle, who developed these pumps, was led to the study of the behaviour of gases. Charles and Gay-Lussac of gas laws fame had vital practical interests in gases. Charles was one of the crew of two on the first hydrogen balloon flight in 1783. Gay-Lussac held the world altitude record for many years having reached a height of 23,000 feet in a balloon flight of 1804.

The fusion of the two traditions, the availability of coal and iron in England and the great need for labour led to the invention of the steam engine by James Watt around 1765. This marked the beginning of the Industrial Era.

Just one example should suffice to convey an idea of the revolution brought about, from the outset, by the harnessing of the energy from coal. In 1760 Arkwright invented his spinning frame. At that time a total of 8000 workers were employed in the textile trade in England. In 1774 the steam engine was sufficiently advanced to put Arkwright's idea into practice and to set up the first mechanical weaving mill. In 1787, the English textile trade had no less than 320,000 workers in employment.

Exploitation of energy from coal led to rapid expansion of industries and transportation over land and sea. More machine power made it possible to produce more goods and more coal, and more coal meant more machine power. This cumulative action made coal a strategic element in the emergence and diffusion of the industrial civilization. Around 1800 the world production of coal amounted to 15 million tons per year. By 1900, it had increased to about 700 million tons and by 1950 to 1500 million tons.

The extraordinary growth in the supply of energy stimulated economic growth, which in turn stimulated education and scientific research leading to, among other technical advances, the discovery of new sources of energy. In 1850, James Young, a Scottish Chemist, established the basis for making of petrol. Thirty five years later, Daimler and Benz cars with their internal combustion engines took successfully to the roads.

While the steam engine brought about the concentration of industries in the cities, the internal combustion engine made it possible to de-centralize and draw in rural population into the process of industrialization.

It would be incorrect to attribute all the progress that has been achieved during the last 100 years or so to the internal combustion engine. For, under the impulse of competition, the steam engine has also continued to develop. But in revolutionizing transport and agriculture, the internal combustion engine has profoundly affected the course of modern industrialization.

In 1820, Faraday began his researches in electricity. By 1870, practical types of direct and alternating current generators became already available. About the same time Edison invented the incandescent lamp. At the Vienna Exhibition of 1883, practically all the electrical appliances of modern life were on show. Since that time, many advances in the large scale-control of energy have centred on electrical energy. Today we have prime movers in the form of electric motors with very large horse-power for use in industry and with very small horse-power for use in small gadgets such as electric shavers.

Electrical energy as we know it today is particularly remarkable for its flexibility, and for the fact that it can be transported for hundreds of miles along cables in almost non-material form. This flexibility and transportability has led to the return to wind and flowing water as sources of energy. The many power wind-mills in Denmark with generating capacities ranging from 30 to 70 kilo-watts are a striking demonstration of future possibilities with wind power. The generation of electricity from running water is a phenomenon we are all familiar with. The source of energy is perennial and the technology is clean and simple.

To bring out clearly the consequences of replacing animate by inanimate prime movers, it is useful to describe these inanimate prime movers as 'energy slaves'. During long periods of history, while animate prime movers were much in use, the material prosperity of a society was determined in terms of the numbers of human slaves and animals that could be mustered for 'getting things done'. By degrees inanimate energy slaves have driven out animate prime movers to such an extent that we find these energy slaves working even in our homes. Today the material prosperity of a society is determined to a large extent by the population of energy slaves that serve that society. It is usual to estimate this population in terms of the energy consumed per person in the society. When a comparision is made between consumption of energy by different nations and their per capita incomes, a broad parallelism is found to exist. For example, the present per capita consumption of inanimate energy in the United States is around 60,000 kilo-watt-hour per year or the equivalent of 600 human slaves; at the other end for India and Ceylon this figure is around 3000 kilo-watt-hour per year or 30 human slaves per person. This disparity in the population of energy slaves in the U.S. and in Ceylon accounts for the prosperity of the former and the poverty of the latter.

An important consideration that must receive our attention now is the nourishment needed for energy slaves. While human slaves and animals require food from green pastures which are perennial, energy slaves, with the exception of those based on wind and water power, need fossil fuels which are the remains of living organisms of prehistoric past. Humanity today is consuming more energy in a single year than has been trapped and stored in a hundred centuries or so by the biological converters of prehistoric times. The question is how long can this fabulous dissipation of stored energy last. Many estimates have been made; some think that the reserves of fossil fuels would last a hundred years; others think that it would last longer. New geological surveys are revealing more and more deposits of fossil fuels, giving rise to a sense of optimism. However, we must admit that hundred years is only a short time in human history, and these energy reserves will some day get exhausted or become unworkable. Fortunately, progress in scientific research has already led us to a new era, long before man has fully exploited the possibilities of fossil fuels—I mean the era of Atomic Energy.

Largely through the work of Rutherford, it became known, as early as at the beginning of this century, that the atom is a store-house of an enormous amount of energy. Research started then has now led to the release of this energy in a practical form in the nuclear reactor. What is most striking is the compactness of the fuel uranium; one pound of uranium on complete fission releases three million times as much energy as a pound of coal. Although the fuel is compact, the apparatus needed to ensure controlled liberation of energy is still rather weighty and bulky. In this respect the development of atomic energy is at present in somewhat the same state as the development of the 18th century steam engine. However, as a source of very large power supplies, such as power stations atomic energy holds out bright promise.

Summing up, we can say that man has been up against Nature right from the beginning of human history. One by one, he has brought under control the energy of food, the energy of wind and water, the energy of gunpowder and fossil fuels and finally the energy of the nuclei of atoms. Every phase in his control of energy has been accompanied by military and social upheavals of a magnitude comparable with the energy released in that phase. Admittedly, the various causes operative in history are so closely bound up together that we cannot contend that, in each phase, the sole and direct cause of social change has been the advance made in the control of energy. Yet, when we examine the question more closely, we almost invariably find that the event in question would not have been possible without such advance. But for the slaves, there would not have been the great civilization of the past; but for the gun, the colonialists would not have conquered the lands across the seas; and but for the steam engine, there would not have been an Industrial Age.

5. LESSON OF HISTORY

Historians are in the habit of labelling changes that occur in history as 'Revolutions'. They had detected several such revolutions during the course of history, as for example the 'Urban Revolution' in early historic times, the 'Commercial Revolution' in the 11th century Europe and so on. But, from our point of view, the most important revolutions have been the Agricultural Revolution of 10 thousand years ago, the Scientific Revolution of the 17th century and the Industrial Revolution of the 18th century. Of these, the first and the last introduced fundamental changes in the economic character of the societies involved. The first revolution was motivated by the need to provide food for the starving population and it transformed hunters and foot-gatherers into farmers and shepherds; the last was motivated by the need to provide labour for productive purposes and it transformed farmers and shepherds into operators of energy slaves fed with inanimate energy. But the Industrial Revolution would have been impossible without the Scientific Revolution which preceded it and brought about the necessary climate for the union of the traditions of the scientist and the traditions of the craftsmen. Modern technology is the result of this union.

The Agricultural Revolution has taken more than nine thousand years to diffuse throughout the world, and yet we find in the remotest parts of the world people whose economy is still based on hunting. On the other hand, it is only two hundred years since the Industrial Revolution in England began; but wherever it penetrated it has rapidly transformed the material prosperity of the society that absorbed it. Imperial

Japan required only forty years, between 1860 and 1900, to catch up with the West and the U.S.S.R. has taken about the same time. At the present state of technology the time ought to be even shorter.

Now let us consider briefly the growth of control of energy in our own country and the factors that impede progress. Techniques and ideas of the Agricultural Revolution were brought into Ceylon twenty-five centuries ago by the early settlers, and since that time Ceylon has continued to remain an agricultural country. The energy requirements of ancient Ceylon were supplied by the muscular power of men and animals. In the execution of public work, men were compelled to perform 'Rajakariya' or service to royalty in return for holdings in land, which belonged to the kings. Slave labour in the form in which it existed in the West was unknown in Ceylon. Even so, ancient Ceylon had reached its own peaks of prosperity. The marvellous irrigation systems it had developed, to harness the energy of water for irrigation, and the magnificient palaces and dagobas it had built bear testimony to the achievements of the past. However, the methods of agriculture have remained substantially unchanged throughout the period of history.

Ceylon came under foreign domination early in the 16th century. At that time there was no cultivation for purposes of trade which was a royal monopoly. The people bartered the produce of their lands for the necessary domestic wants such as salt, fish, cloth and the like. Still more significant is the fact that anything beyond these needs was of no use to anybody. For, under the rigid rules of caste, no man could better his occupation or dwelling or raiment.

This rigidity in the social set up, while it helped the people to maintain their craft traditions, had killed motivation and prevented them from adapting themselves to changes that were so vital to the progress of society. In this sense, society in Ceylon had remained sterile in thought and static in action, without any form of jolting stimuli that awoke Europe from its slumbers during the same period.

Plantation agriculture was introduced into Ceylon by the British Planters in 1839. Though tea grew well in this country, its manufacture at the start was difficult and cost prohibitive. With the introduction of skilled human labour for pruning and plucking, and energy slaves in the factories and on the railroads, the tea industry began to flourish. In 1873, the area under tea was 280 acres; in 1893 it had expanded to 270,000

acres and now it is nearly 600,000 acres. This industry, which is an outstanding example of the judicious use of human labour for its skill and adaptability and of energy slaves for work which does not require such qualities, today accounts for nearly 2/3 of the countries export earnings. However, inhibitions engendered by the rules of caste have prevented our rural population from actively participating in this great venture.

Pressed with the problems of under-development, we are now endeavouring to transform our economy based on subsistence agriculture to one based on techniques and ideas of the Industrial Revolution, that is, on science and modern technology. But we must realize that farmers and cowherds cannot be transformed into scientists and operators of energy slaves almost overnight by the mere increase in the supply of their tools and other implements. The revolutionary transformation needs fundamental changes in our inhibitions and habits, ideas and motivations, besides the need for capital. Hence our primary task should be to re-model our human resources through the right type of education at all levels.

If a scientific outlook so necessary to the growth of technology is to be made a part of the mental make-up of an individual to fit the new age, then clearly his education has to be moulded accordingly. Not only must science be taught at the secondary school stage, but his scientific education must commence much earlier with the help of scientific toys, models and products of our own craft techniques. For, as Karl Marx had said,'an early combination of productive labour with education is one of the most potent means for the transformation of present-day society' (Marx, 1875).

It is widely acknowledged that Cottage Industries are the best forms of Industries for a country like ours with limited capital and prolific human resources. But, if as we have seen, a worker were to depend on the energy of his own muscular activity, his out-put of energy will be at the most 100 kilo-watt-hour for the year. If on the other hand, he were to use energy slaves, his out-put would be increased even a hundred fold. The productivity of labour would then be proportionately high. Only in such a situation can motivation be generated in the worker. The prime need for the growth of Cottage Industries is therefore the provision of electricity in the rural areas and the free flow of suitable energy slaves.

For a quick take off, development on a short term basis is very necessary. There are many technologies in the world's well-stocked 'super-market' which are available to be bought. The majority of our most urgent needs come into this category of available technologies. Transport devices, textiles, cement, paper and so on are all examples of technologies we have bought from developed countries. These require an adequate supply of operators of energy slaves—scientists, technologists etc.—to keep them profitably occupied all the time. Institutes for the training of personnel are therefore an urgent necessity.

Failure to attend to operational principles governing the distribution of work between human labour and energy slaves can often lead to losses in industry. A familiar example is our sugar industry, where, we are told, that energy slaves enjoy longer periods of rest and relaxation than human beings. Another example of waste of the working time of energy slaves relates to the use of motor cars. Energy slaves of this type can often be seen parked for hours on end within the city. Most of them do not perform their task for more than two hours per day. Hence, their operational efficiency is less than 10 per cent. On a national scale therefore investment in motor cars is a sheer waste of capital and arises from the lack of a satisfactory system of public transport. Waste of human labour on a national scale in the public sector is not unknown. Sound managerial training of personnel in charge of industrial organizations is therefore another urgent requirement.

In striving for rapid industrialization, we should not overlook the great need to produce enough food for our people. For, it is now feared that human beings will have to face starvation long before energy slaves. We should realize that Ceylon is essentially an agricultural country and has a background of agricultural experience. Due probably to the religious susceptibilities of its people, it had in the past neglected the development of its animal converters. It seem to me that the application of modern agricultural technology coupled with the development of our resources in plant and animal converters should make us self-sufficient with regard to food. An example I have in mind is the case of Denmark. This country has no coal or important mineral deposits, and in the middle of the last century it was predominantly an agricultural country with grain as its chief export. With the export to Europe of grain from the U.S., Denmark was forced to the wall. It had to export or perish and it could no longer export grain. In these circumstances it quickly switched over to scientific agriculture and started producing bacon, eggs, butter and other dairy products. Today Denmark is a flourishing country with enough food for itself and plenty to export.

As I have already indicated, the material prosperity of the U.S. is equivalent to 600 human slaves per person and that of Ceylon to 30 human slaves. But we must remember that the U.S. has to provide for its elaborate defence organization, Parkinsonian expansion of work and waste. If we make allowances for all these and avoid waste ourselves, even a moderate exploitation of energy slaves should raise our standard of living to a satisfactory level. No amount of shuffling with arguments, juggling with wages, or depreciating the purchasing value of paper money can alter economic realities. If the burdens to be carried per head of population increase faster than the population of energy slaves that help to carry them, the material standard of living is almost certain to decline. Unfortunately, those who are aware of the increasing burdens arising from a large proportion of untrained people and an equally large proportion of social commitments guaranteed by the State, have remained comparatively detached from the vital need to educate out community to higher productivity.

From a long term point of view, technology cannot be expected to progress without progress in science on which it so much depends. This underlines the importance of scientific research. The progress of science in the developed countries during the past two hundred years indicates an exponential growth rate in the content of scientific knowledge and in the number of scientifically trained personnel. The doubling time for the last two decades is found to be 10 to 11 years. If selective breeding of plants and animals are considered vital for the development of agriculture, the same should be true of scientists and science, and we should 'grow' our scientists. Most advanced countries are still offering inducements to scientists in the form of pay and prospects to keep expanding their pool. On the other hand, we are losing our best talents due to unattractive terms of employment. An urgent necessity is therefore the immediate arrest of this 'brain-drain' and the recall of those who have left our shores.

Scientific research can be broadly classified into two groups, namely, basic research and orientated research. Basic research is what usually goes on in a University; but orientated research is directed towards a specific objective, as for example, the control of Blister Blight in tea. Both types of research should be encouraged in allour Universities and other Institutions. From the point of view of a developing country like ours, it is orientated research that seems to be of immediate importance. An essential requirement for the promotion of such research is the close collaboration of the teachers in our Universities and research workers in other organizations. But research like any other undertaking requires men, money and material. When the various research organizations are distributed under different Ministries, collaboration becomes impossible without a central authority like a National Research Council.

Finally, I would like to touch on another important point, and that is the role of administration in science. I cannot do better than quote the words of that distinguished Indian scientist and leader, the late Dr. H. J. Bhabha. I do so partly for the lessons we may learn from them, and partly as a tribute to a former Chief Guest who saw far more clearly than we do what an under-developed country like ours needs:

'It is thought by many that we are reasonably advanced in administration but backward in science and technology. This statement is misleading. We have fortunately inherited extremely competent administrative services capable of dealing with all types of administration which had to be dealt with before Independence, in what was intended to be a static and under-developing economy. Consequently, experience of the type of administration needed for industry and for science and technology has been lacking. The type of administration required for the growth of science and technology is quite different from the type of administration required for the operation of industrial enterprises, and both of these are again quite different from the type of administration required for such matters as preservation of law and order, administration of justice, finance and so on. It is my personal view, which is shared by many eminent foreign scientists, that the general absence of the proper administrative set-up for science is a bigger obstacle to the rapid growth of science and technology than the paucity of scientists and technologists; because a majority of the scientists and technologists we have are made less effective through the lack of the right type of administrative support. The administration of scientific research and development is an even more subtle matter than the administration of industrial enterprises, and I am convinced that it cannot be done on the basis of borrowed knowledge. It must necessarily be done, as in the technologically advanced countries, by scientists and technologists themselves' (Bhabha, 1966).

References

BHABHA, H.J. (1956), '*Science and the Problem of Development*', Invitation Lecture: International Council of Scientific Unions (1966).

MARX, K., 'Critique of the Gotha Programme' 1875 as quoted by DENNIS GABOR in '*Inventing the Future*' p. 27; Pelican Book (1964).

TIRASPOLSKY, W., 'Energy as the Key to Social Evolution'. *Impact* 3, 7.

SECTION A—MEDICAL AND VETERINARY SCIENCES

Presidential Address

THE CHEMICAL BASIS OF DISEASE

by

T. W. WIKRAMANAYAKE

Till the end of the 18th century the treatment of disease lacked any scientific foundation. Though many contributions had been made towards the advance of the knowledge of the structure of the body little was understood of its function. It is not surprising, therefore, that treatment was determined by the personal opinions and prejudices of the physician, and was dictated by a general belief in magic spells. In the 19th century there was a significant advance in anatomy, histology, pathology and bacteriology and the nature of many disease processes began to be understood. There were, however, only a few instances in which this new knowledge could be translated into therapy. In a majority of illnesses, rest in bed and good nursing and the treatment of symptoms were all that could be offered. The magical element in medicine persisted even in the early part of this century. For instance, the word "diathesis" was often used in explaining away many conditions. A lithaemic diathesis was believed to be the underlying causative factor of such conditions as chronic eczema, gout, arteriosclerosis and even cirrhosis of the liver. The term tuberculous diathesis was in vogue even as recently as 30 years ago. In many instances such beliefs had no factual basis at all. In other cases, though based on existing knowledge, the belief was carried far beyond what was justified by the evidence available, merely because the idea appeared plausible. If witch-craft and magic have disappeared from medicine today, it is undoubtedly due to the contribution made by chemistry and physics in the understanding of disease. The use of new physical and chemical methods in the investigation of disease processes has assisted greatly in medical research, which in turn has provided an explanation of the chemical basis of disease. It has also led to the discovery of newer techniques and tests which are now the foundations of diagnosis, prognosis and treatment.

The biochemist's objective is that of describing in chemical terms the dynamic workings of the living cell and showing how the activities of cells are integrated in the functioning of the whole organism. In this he has been greatly assisted by the physiologist and the electron microscopist. These investigations have led him to the knowledge of the biochemical alterations in metabolism that are responsible for many disease processes. In some instances such knowledge has helped the clinician to meet the disease at a point where it is still reversible. In others the connection between biochemistry and therapy is still not clear.

Biochemical alterations in metabolism can be divided into those that are due to the acquired biochemical lesions, and those that are permanent and built in, involving genes.

BIOCHEMICAL LESIONS

The term "Biochemical Lesion" was first introduced by Rudolph Peters (1936) "to crystallise the idea that pathological disturbances in tissues were initiated by changes in biochemistry". Biochemical analysis may therefore provide evidence of an altered function of a cell before histological abnormality is detectable. The life of a cell depends on an orderly sequence of enzyme activity. Many of the known biochemical lesions are due to changes in the orderly activity of these enzymes or enzyme systems.

It was the work on thiamine deficiency and convulsions which led Peters to the first proposal of the term "Biochemical lesion". In 1889, Eijkman, a Dutch physician working in Java, had found that hens kept on a diet consisting mainly of a highly polished rice developed head retraction and convulsions of a particular type. When the diet was changed to one of undermilled rice the birds recovered completely. Grijns, who succeeded Eijkman in the Dutch East Indies, had interpreted this as being due to a deficiency in the diet. Other birds such as pigeons were found to behave in a like manner. Peters used pigeons made deficient in thiamine by keeping them on polished rice, for testing the potency of various thiamine preparations.

Birds kept on a diet of highly polished rice developed a condition called "opisthotonus", which could be cured by injections of thiamine (vitamin B_1). The effect of thiamine injections could be demonstrated within 15 min. In the acute stage no pathological changes can be detected with the light microscope. It is unlikely that any such change, even i

it did exist, would clear up in 15 min., so that this is a good example of a pure biochemical lesion. Thiamine was shown to function as thiamine pyrophosphate (TPP) which is a coenzyme to a decarboxylase which oxidises pyruvic acid. A low concentration of TPP results in lowered utilisation of oxygen by brain tissue, which is responsible for the abnormal condition of the bird.

Subsequent work has shown that most vitamins are components of enzyme systems, but the relationship between the signs and symptoms of deficiency and their known metabolic roles is less apparent than in the case of vitamin B_1.

Another biochemical lesion demonstrated by Peters and his group at Oxford (Stocken & Thompson, 1946) was the action of certain arsenicals on tissue metabolism. During World War II much attention was given to organic trivalent arsenical irritant gases. One of these, lewisite, $AsCHCl_2{=}CHCl$, combines through its mono-substituted arsenic atom with the contiguous thiol groups in lipoic acid forming a ring compound which is very stable.

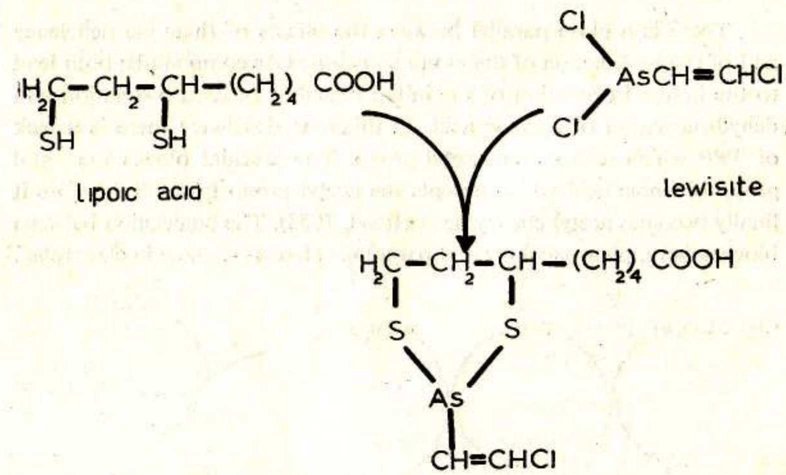

Fig. A

The union can be reversed by the transfer of the =As- grouping to 2:3—dimercapto-propianol, because the five-membered ring formed by the latter is more stable than that with the tissue component. Hence the action of lewisite can be reversed or prevented through a reversal of the chemical attack upon the intracellular enzymes concerned, even after the commencement of the pathological change:

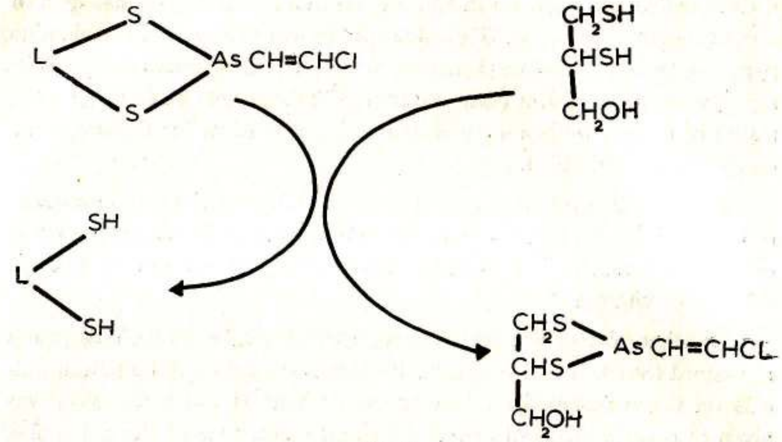

Fig. B

This is probably the first instance in which a therapeutic substance has been discovered by a logical theoretical approach, i.e. one based on chemistry.

There is a close parallel between the effects of thiamine deficiency and of the toxic action of the mono-substituted As compounds: both lead to the failure in function of the initial reactions of decarboxylation and dehydrogenation of pyruvic acid. In thiamine deficiency there is a lack of TPP which accepts the acetyl group. The arsenial blocks the thiol group of lipoic acid which accepts the acetyl group from TPP before it finally becomes acetyl coenzyme A (Reed, 1953). The connection between biochemistry, pharmacology and pathology stands out here in clear relief.

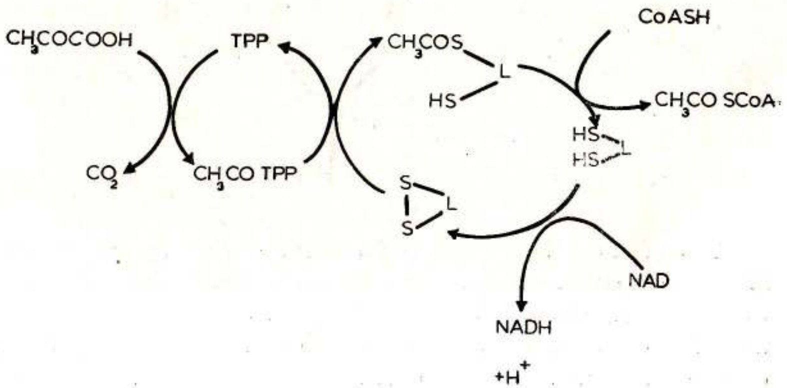

Fig. C

Yet another biochemical lesion studied by the Oxford group is that produced by carbon-fluorine compounds like fluoro-acetate (Liêbecq & Peters, 1949). This compound has been extracted from certain S. African plants. When ingested the leaves may induce poisoning in animals. Investigation of the mode of action of fluoroacetate revealed a new type of toxicity. The actual biochemical lesion is also in this case an attack upon an enzyme, but only after the compound has undergone a synthesis carried out by the enzymes found in the tissues. Flouroacetate is not in itself toxic to enzymes. It is misguidedly used by the cell and synthesised into fluorocitric acid. Minute amounts of this new compound inhibits the enzyme aconitase which is required for further metabolism of C_6

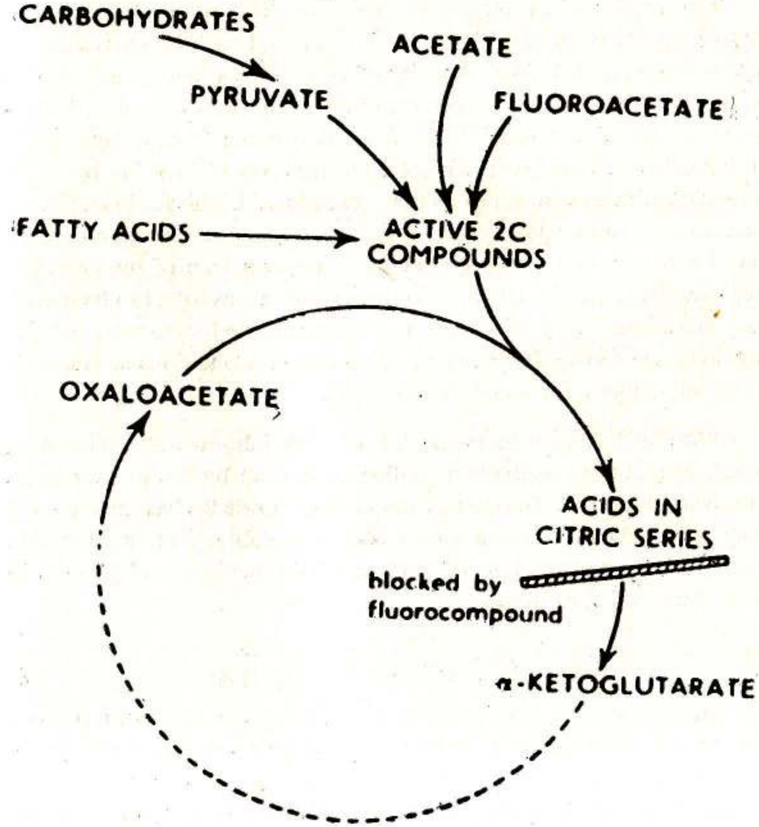

Fig. 1. Illustrates the hypothesis for the mechanism of lethal synthesis and shows the channel by which fluoroacetate becomes synthesised to fluorocitrate.

acids. Thus, a compound, harmless by itself, is joined with relatively innocuous cellular metabolites to bring about serious disturbances of cell function. A "lethal synthesis" has thus being achieved.

The exploration of this biochemical lesion has thrown light upon various natural poisons. It has also provided the biochemist with a new tool for exploring intermediary metabolism, because as far as is known fluorocitrate is specific in its blocking action on aconitase. The study of the phenomenon of lethal synthesis has been followed by remarkable developments in the field of genetics and of cytology (Peters, 1963).

INBORN ERRORS OF METABOLISM

The activity of an enzyme system can therefore be interfered with by toxic agents or by nutritional deficiencies, and such interference gives rise to biochemical lesions. Activity of an enzyme system could also be interfered with (or brought to a standstill) if the enzyme protein is deficient (or altogether absent). This idea was first put forward by Garrod in 1923. He was studying a black substance passed in urine by some patients, which was shown to be homogentisic acid. This acid is an intermediate in the break-down of the amino-acid, tyrosine. Garrod conceived the idea that the enzyme required for the metabolism of homogentisic acid was absent in his patients. As the condition was found to be hereditary he said that a mutation of the gene responsible for carrying out this reaction gave rise to the pathological condition. Conditions such as this he called "Inborn Errors of Metabolism".

Since 1923 a very large number of such inborn errors have been described and the metabolic alterations produced by the mutant genes have been elucidated. The greatest amount of knowledge has accumulated from the study of different forms of haemoglobin, and haemoglobin synthesis is a good example of the role of biochemistry and genetics in the understanding of disease.

THE HAEMOGLOBINOPATHIES

Haemoglobin is a conjugated protein, i.e. it is made up of a protein, globin, and a non-protein moiety (referred to as a prosthetic group) which is an iron-porphyrin. Globin consists of four polypeptide chains, each chain being a coiled structure with one iron-porphyrin sitting in a pocket formed by each coil. Most haemoglobins consist of two dimers, each dimer being formed by two similar polypeptide chains. Various

haemoglobins appear in the blood during different stages of development of an individual, differing in the kinds of polypeptide chain that make up the globin molecule.

In the adult the major component referred to as Hb-A, is built up of two polypeptide chains of one kind, called alpha-chains, and two of another, called beta-chains. It can be represented thus: $\alpha_2^A\beta_2^A$, the superscripts denoting the source of each chain (i.e. from Hb-A), while the subscripts denote the number of each type of chain present. The amino acid sequence of each chain is known. The β-chain has 5 amino acids more than the α-chain. There are 84 differences between the two chains.

A second haemoglobin, called Hb-A_2, occurs in all haemolysates after the postnatal period and amounts to about 3% of the total haemoglobin. It consists of 4 polypeptide chains, two of which are identical with the α-chains of Hb-A. The other two differ from the β-chains by 10 amino acid substitutions and have been called delta-chains. Hb-A_2 could be denoted as $\alpha_2^A\delta_2^A$.

In foetal life, the major component of haemoglobin is Hb-F. It constitutes 70-80% of the total Hb of a full term foetus. It consists of 4 polypeptide chains, two of which are identical with the α-chains of Hb-A. The other two have the same number of amino acid residues as the β-chains but differ from them in 39 amino acid substitutions. They are called γ-chains. Hb-F is therefore $\alpha_2^A\gamma_2^F$.

Several minor haemoglobins have been described in foetal blood. The largest of these is Hb-F_1, with a structure $\alpha_2^A\gamma^F\gamma^X$. A small amount of Hb-$\gamma_4$ is also present.

Two other haemoglobins have been isolated from the embryo, and are called Hb-Gower 1 and Hb-Gower 2. In Hb-Gower 2 there are 2 α-chains and two other chains called ϵ-chains. It is therefore $\alpha_2^A\epsilon_2$. Hb-Gower 1 probably has 4 ϵ-chains. The youngest embryo studied, with a crown-rump (CR) measurement of 25 mm., had mainly Hb-F, 24% of Hb-Gower 1, 13% of Hb-Gower 2 and about 5% of Hb-A and 1% of Hb-γ_4.

The concentration of embryonic haemoglobin falls rapidly as development proceeds, and they are not present after the 100 mm. CR stage of development.

The synthesis of α-and β-chains of Hb-A are controlled by pairs of genes at different genetic loci on the chromosome. The genotype of Hb-A can therefore be written:

$Hb\alpha^A/Hb\alpha^A \quad Hb\beta^A/Hb\beta^A$.

The superscript A indicates that the gene is controlling the synthesis of a normal peptide chain.

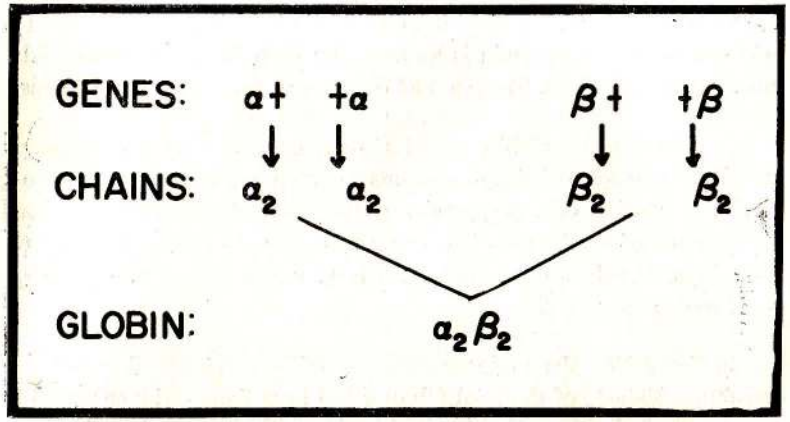

Fig. 2. Schematic model for synthesis of the globin portion of hemoglobin. This graphically illustrates the independent synthesis of alpha and beta chains, and the final formation of the four chain unit by random combination of alpha and beta units.

Figure 2 shows a model that explains the synthesis of the polypeptide chains of Hb-A. According to this, each gene controls the independent synthesis of each kind of polypeptide chain, two of which form a dimer, and these dimers unite to produce a 4-chain unit by random combination of α-and β-units.

The α-chains are common to all the haemoglobins found in the different stages of development, embryonic, foetal and post-natal. They are therefore synthesised throughout life. It is not known when the synthesis of δ-chains commences. Hb-A_2 is found in foetuses towards the end of pregnancy. Hb-A appears in the 13th week of foetal life, which is therefore the period at which β-chain synthesis commences. As the concentration of HbA in the foetus increases with development, that of Hb-F decreases until Hb-A completely replaces Hb-F by the end of the first year of post-natal life.

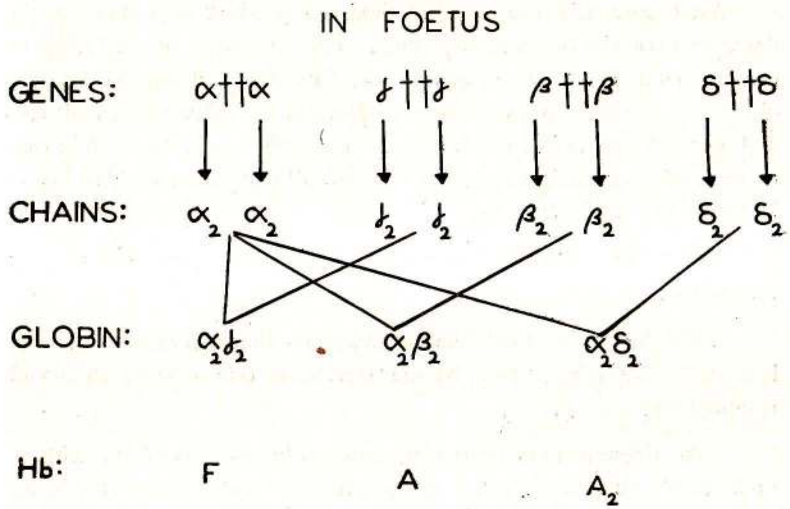

Fig. 3. Schematic model for synthesis of Hb-F, Hb-A and Hb-A2 during foetal life.

In foetal life, a person manufactures primarily Hb-F. He is synthesising α-and γ-units. As he matures he switches over to the manufacture of Hb-A, i.e. to α-and β-units. Since α-chain synthesis in unchanged, the transition from Hb-F to Hb-A manufacture is really the turning off γ-chain manufacture and the turning on of β-chain manufacture.

This is the best example in man of a chemically defined developmental process.

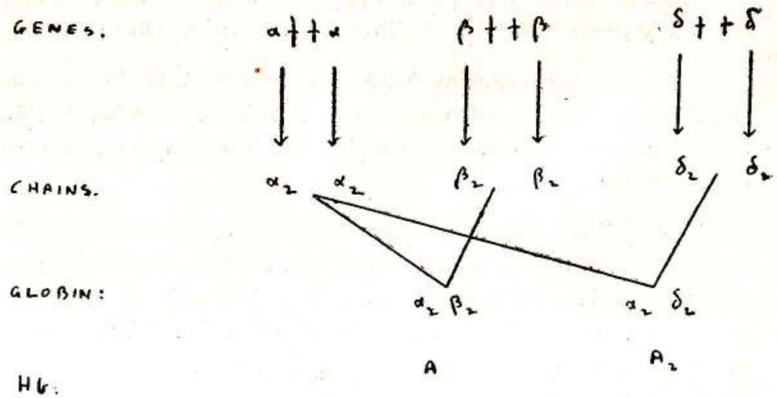

Fig. 4. Schematic model for synthesis of Hb-A and Hb-A2 during post-natal Life.

What happens if the gene inherited is defective? A person who is defective in one or both of his β-chain genes should not be fully affected during foetal life, as the foetus does not require β-chains. As he gets older and attempts to switch over to β-chain manufacture, his disease will manifest itself. On the other hand, a person who is defective in one or both of his α-chain genes should have full expression of his disease in both foetal and adult life.

Two kinds of disturbances in haemoglobin synthesis are now recognised:

1. The best understood defect, and the one that was first recognised, is a qualitative defect, shown by the presence of one or more abnormal haemoglobins.

2. A different type of defect, apparently not associated with a qualitatively abnormal product, but resulting in an alteration in the quantity of haemoglobin synthesised.

1. The Abnormal Haemoglobins

There is a qualitative difference between the abnormal haemoglobins and the normal haemoglobins. There could, therefore, be Hb-A variants, Hb-A_2 variants and Hb-F variants.

Hb-A variants:

There are some 50-60 variants of Hb-A studied to date. Of these, the clinically important ones are Hb-S, some of Hb-Ds, Hb-E and Hb-H.

All these haemoglobins have one characteristic in common, they are made up of 4 polypeptide chains. With the exception of a few, they contain two α-chains and two β-chains. Many of them have been chemically identified.

Table 1 lists a few of the abnormal haemoglobins. The difference between each of these and Hb-A consists in the replacement of a single amino acid residue in Hb-A by a new residue in the abnormal Hb. Such substitutions can occur in the α-chain or in the β-chain. In Hb-S, for instance, the difference lies in the β-chain and consists in the replacement of the sixth amino acid in the β-chain (which is glutamic acid, glu) of Hb-A with valine (val).

Table 1

Some chemically identified human haemoglobins

Name	*Chain Composition*	*Amino Acid Substitution*
Hb S	$\alpha_2 \beta_2^*$	β_6, glu→val
Hb C	$\alpha_2 \beta_2^*$	β_6, glu→lys
Hb $G_{San\ Jose}$	$\alpha_2 \beta_2^*$	β_7, glu→gly
Hb E	$\alpha_2 \beta_2^*$	β_{26}, glu→lys
Hb $M_{Saskatoon}$	$\alpha_2 \beta_2^*$	β_{63}, his→tyr
Hb Zurich	$\alpha_2 \beta_2^*$	β_{63}, his→arg
Hb $M_{Milwaukee-1}$	$\alpha_2 \beta_2^*$	β_{67}, val→glu
Hb D_{Punjab}	$\alpha_2 \beta_2^*$	β_{121}, glu→gln
Hb O_{Arabia}	$\alpha_2 \beta_2^*$	β_{121}, glu→lys
Hb I	$\alpha_2^* \beta_2$	α_{16}, lys→asp
Hb $G_{Honolulu}$	$\alpha_2^* \beta_2$	α_{30}, glu→gln
Hb Norfolk	$\alpha_2^* \beta_2$	α_{57}, gly→asp
Hb M_{Boston}	$\alpha_2^* \beta_2$	α_{58}, his→tyr
Hb $G_{Philadelphia}$	$\alpha_2^* \beta_2$	α_{68}, asp→lys
Hb $O_{Indonesia}$	$\alpha_2^* \beta_2$	α_{116}, glu→lys
Hb H	β_4	None
Hb Bart's	γ_4	None

The substitution of one amino acid by another brings about a change in the net charge and an alteration in the electrophoretic mobility of the molecule, making its detection possible. The amino acid substitutions that have been reported probably occur where the residues are on the surface of the molecule, in contact with water molecules. Water is required for the ionization of the amino acid residues, and ionization results in an alteration in the charge carried by the molecule. If an amino acid in the centre of the molecule is substituted by another, because this is not in contact with water molecule it may not ionize, and there may be no apparent differences between the new Hb and the normal Hb. Therefore it is possible that there are many more abnormal Hbs, abnormal in the chemical sense but not detectable by present methods. Techniques such as electrophoresis will help in detecting these anomaies only if the exchange of amino acids is accompanied by a modification

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of the electric charge on the molecule. With the use of better and more varied techniques in the study of amino acid sequence of these proteins, it is possible that more abnormal Hbs will be discovered.

Hb-S is one of the clinically important Hb-A variants, and one of the earliest to be discovered. When blood from a patient with this Hb in his red cells is exposed to a reduced oxygen tension i.e. when it is deoxygenated, the shape of the cell changes from a biconcave disc to a sickle-shaped form. There is a marked increase in the viscosity of the haemoglobin and gelation occurs if there is more than 10% Hb-S in the cell, resulting in the altered shape. This is a reversible change. The rapidity and the severity of the sickling process depends on the proportion of Hb-S present in the cell.

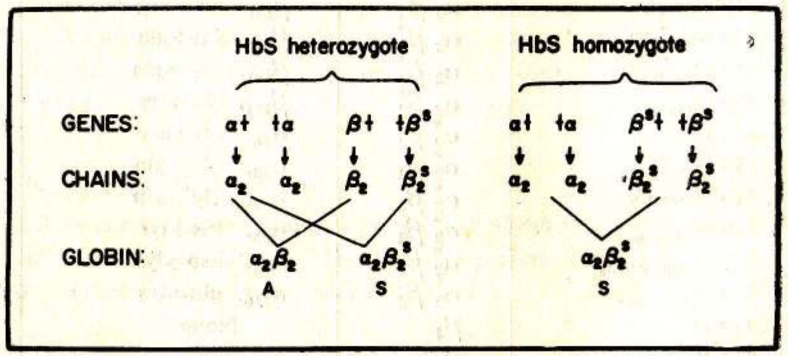


Fig. 5. *Left*, schematic model for synthesis of hemoglobin in a Hb S heterozygote (sickle cell trait). *Right*, schematic model for a Hb S homozygote (sickle cell anemia).

Figure 5 shows the genetic model for the inheritance of Hb-S. The defect is in the β-chain. The formula of Hb-S may be written $\alpha_2^A\beta_2^S$. In agreement with the clinical findings the model predicts that a person homozygous for Hb-S (i.e. with sickle cell anaemia), will produce Hb-S, not Hb-A. The heterozygote (i.e. sickle cell trait) will synthesise both Hb-A and Hb-S.

The occurrence of haemoglobin molecules abnormal in both peptide chains allows one to make certain deductions about the mode of assembly of the haemoglobin molecule. The persons with four haemoglobins are doubly heterozygous, having the genotype $\alpha^A/\alpha^G \quad \beta^A/\beta$. Apparently each gene causes the manufacture of a peptide chain characteristic of it, so that four types of peptide chains are produced in these persons.

Because haemoglobin molecules having two different α- or β-chains, such as $\alpha^A\alpha^G \ \beta_2^A$, or $\alpha_2^A\beta^A\beta^S$ have never been observed, it has to be assumed that each gene controls the synthesis of a dimer (Baglioni, 1963). The chains probably have to dimerize in order to be released in solution. The different types of dimers present assemble in a random fashion to complete the haemoglobin molecule, leading to all the possible combinations. (Fig. 6).

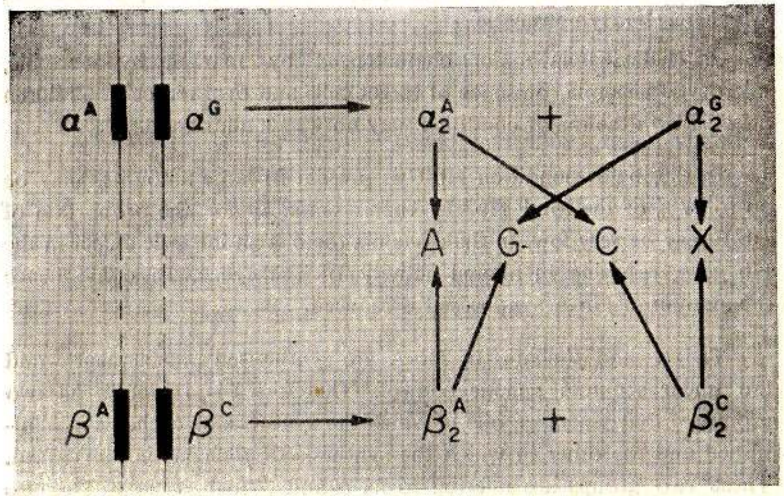


Fig. 6. Schematic explanation of the presence of four haemoglobins in doubly heterozygous individuals. The loci controlling the synthesis of α and β chains are represented on the left. The arrows show the different dimers synthesised, and the random combination of these dimers. Hb-A results from the combination of α_2^A dimers with β_2^A dimers, Hb-G from α_2^G dimers and β_2^A dimers, Hb-C from α_2^A and β_2^C dimers, and Hb-X from α_2^G and β_2^C dimers.

Abnormal haemoglobins differing from Hb-F and Hb-A_2, i.e. Hb-F variants and Hb-A_2 variants, are also known. Those subjects who synthesise abnormal α-chains will have abnormal Hb-F and abnormal Hb-A_2, in addition to Hb-A variants, as the α-chain is common to all the normal Hbs. For instance, an individual with Hb-G ($\alpha_2^G \ \beta_2^A$) would during foetal life have an abnormal Hb-F, namely Hb-G/F ($\alpha_2^G \ \gamma_2^F$). Hb-F with altered γ-chains and Hb-A_2 with alterations in the δ-chains have been reported.

2. The Thalassaemia Syndrome

A condition first described by Cooley and called Cooley's anaemia or thalassaemia (mediterranean anaemia) is a widespread hereditary disease which occurs most commonly in mediterranean peoples, especially of Italian and Greek origin.

Two main clinical forms of this syndrome are recognised:

1. Thalassaemia minor: a mild, hypochromic microcytic anaemia, which may be asymptomatic.

2. Thalassaemia major: characterised by marked hypochromic, microcytic anaemia, presence of target cells and oval red cells. Children affected with the major condition may not reach adulthood.

In the major condition Hb-F is present in large amounts, may be up to 97% of the total Hb. In thalassaemia minor the proportion of Hb-F may be very low. In thalassaemia there is an intrinsic defect in the Hb gene, resulting in altered activity of that gene. In consequence the amount of Hb-A synthesised is reduced.

The α -and β-chains of Hb-A are synthesised independently and are under separate genetic control. Therefore there would be two groups of thalassaemias, one in which the synthesis of α-chains is diminished and the other in which the synthesis of β-chains is diminished. These two groups are referred to as α-and β-thalassaemias. Because the normal Hbs have γ- and δ-chains, one would expect to find γ- and δ-thalassaemias as well. One patient with no Hb-A_2 has been reported and might well be a case of δ-thalassaemia. The existence of γ-thalassaemia has been claimed. However, the only two established groups are α- and β-thalassaemia.

In α-thalassaemia synthesis of both Hb-A and Hb-A_2 is diminished. The disease should manifest itself in both foetal and adult life, because the α-chains are needed for Hb-F also. In β-thalassaemia the abnormality shows up only in post-natal life. In both, Hb-A synthesis is reduced, and Hb-F appears in the red cells as a compensatory phenomenon.

There could be several different mutations, leading to varying degrees of impairment of polypeptide chain synthesis. Some mutations would completely, or almost completely, inhibit the synthesis of a particular polypeptide chain. Others would only partially inhibit it. There

could thus be a whole range of mutations causing varying degrees of inhibition in the synthesis either of α- or β-chains, and the degree of inhibition would be indicated by the amount of Hb-A in circulation.

The term thalassaemia, therefore, includes a group of hereditary anaemias, heterogeneous from a genetic point of view. The genetic defect could be one or more of a very large number of possible defects, all of which produce the same phenotype, viz. reduced Hb-A synthesis, and a compensatory increase or a persistence of Hb-F manufacture. The genes causing thalassaemia can occur in the heterozygous or homozygous state, giving rise to thalassaemia trait or the thalassaemia major condition.

The study of the abnormal haemoglobins shows that one role of the genes is the determination of the amino acid sequence of proteins. Genes with such structure-determining properties are known as "structural genes".

Structural genes are not sufficient, however, to explain other genetically controlled mechanisms. For instance, the termination of Hb-F production and the beginning of Hb-A production in the normal infant must involve a gene. Instances are known of people with an inherited defect in this mechanism, with persistence of Hb-F production in adult life. The gene appears to control the activity of the β-chain gene or the γ-chain gene, or both. This gene may be a regulatory gene. The activity of many structural genes may be controlled by regulatory genes.

A regulatory gene probably explains why Hb-A_2 comprises only about 2.5% of the total Hb and Hb-A 96-97%. These proportions may reflect a control over the relative activity of the β- and δ-chain genes.

Again, in the sickle-cell-Hb-C disease, both Hb-S and Hb-C are present, but Hb-S is in greater concentration than Hb-C. Therefore the rate of synthesis of Hb-S is greater than that of Hb-C. When Hb-A and an abnormal Hb are both found in the same cell, Hb-A is always present in higher proportion than the other. Therefore the rate of synthesis of Hb-A is rapid when compared with the rate of synthesis of the abnormal Hbs.

The presence of an abnormal Hb is associated with abnormalities in red cell morphology and definite clinical manifestations. Due to the slow rate of synthesis of the abnormal Hb, the cell is poorly haemoglobinished and the patient suffers from anaemia. To compensate for the deficiency of Hb, Hb-F synthesis persists in adult life, so that abnormal Hb-A variants are accompained by the presence of Hb-F in the red cells. The cells are usually microcytic and numerous target cells appear. Target cells result from a disproportionately high cell surface, and this can be due to an inhibition of Hb synthesis without a corresponding inhibition of stroma synthesis.

Genetic Control of Protein Synthesis

How do genes determine the structure of proteins synthesised in the cytoplasm of the cell?

The genetic information is carried by molecules of deoxyribonucleic acid (DNA) which form the chromatin threads of the chromosomes. The chromosomes are polytene, i.e. they contain high multiples of each chromosomal strand associated in parallel. The information carried by the DNA is transferred from the nucleus to the site of protein synthesis by molecules of ribonucleic acid (RNA) which are synthesised in the nucleus, under the direct influence of the DNA. Nuclear RNA is synthesised along the whole length of the chromosome. Accumulations of RNA can be seen in association with the transverse bands of chromosomes and are called "puffs". The pattern of "puffing" is characteristic for each cell type, and, in a particular cell, puffing will vary with different physiological states. The formation of a puff at a given locus represents an increase in the state of activity of the genes at that locus (Harris, 1965).

When animal cells are exposed to a radioactive RNA precursor, the RNA in the cell nucleus becomes labelled much more rapidly than does the RNA in the cytoplasm (Bergstrand, Eliasson, Hammarsten, Norberg, Reichard & Von Ubisch, 1948; Wikramanayake, Heagy & Munro, 1953). Much of this nuclear RNA is continuously made and broken down in the nucleolus, and only a small proportion of the RNA made on the genes is transferred to the cytoplasm to serve as a template for protein synthesis. This RNA is referred to as messenger RNA or m-RNA.

About 75% of the RNA in the cytoplasm is associated with protein in particles called the ribosomes. The m-RNA gets attached to these ribosomes which form the factory for the manufacture of proteins.

Another form of RNA in the cytoplasm exists as small molecular RNA. These combine with amino-acids that enter the cell. They are called transfer-RNA or t-RNA. There is specific t-RNA for each amino acid

and a specific enzyme system for activating each amino acid. The t-RNA which accepts one amino acid appears to contain a sequence of nucleotides different from the t-RNA which accepts another.

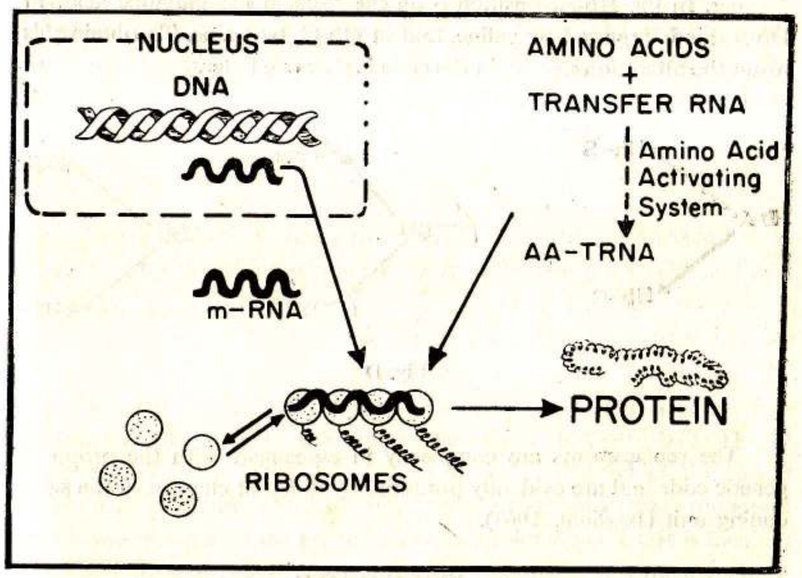


Fig. 7. Protein Synthesis.
m-RNA = messenger RNA, synthesised in nucleus. AA-TRNA = combination of amino-acid with its specific transfer RNA.

Each amino acid is brought to the ribosome by its specific t-RNA, and the t-RNAs are assembled on the ribosome in a particular sequence, a sequence that is determined by a particular fit between the nucleotides of the t-RNA and the nucleotides of the m-RNA. The fit is determined by the purine and pyrimidine bases in these nucleotides. The base sequence of the m-RNA is influenced by that of the DNA, so that DNA controls the sequence in which the amino acids are lined up on the ribosomes, i.e. the sequence of amino acids in the polypeptide that is synthesised.

Both DNA and m-RNA are polymers, with sequences of only 4 different nucleotide units. The 4 bases of these nucleotides control the order in which some 20 different amino acids are arranged. The minimum coding unit would be a 3 letter one, or a multiple of 3 bases. The RNA code for each amino acid has been worked out experimentally (Nirenberg & Jones, 1963). How does this code agree with the known alterations in the amino acid sequence of the haemoglobins?

e.g. In the Hb-A, position 6 on the β-chain has glutamic acid. In Hb-S this is replaced by valine, and in Hb-C, by lysine. To obtain this result the alteration needed in the code is that one letter.

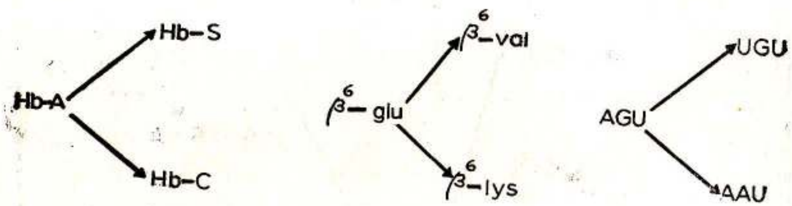


Fig. D

The replacements are completely in agreement with the proposed genetic code and are evidently produced by different changes in the same coding unit (Baglioni, 1963).

ISOENZYMES

The observation that sickle cell haemoglobin moves more slowly in an electrophoretic field than does normal haemoglobin was one of the first demonstrations of human diversity at the molecular level. In recent times a similar form of diversity has been recognised in which multiple forms of an enzyme with the same substrate specificity may exist in a single tissue or even in the same cell. The term "isozyme" or "isoenzyme" has been proposed for this form of enzyme heterogeneity. These different molecular forms in which an enzyme may exist have been identified mainly because of their electrophoretic differences. But isoenzymes have been distinguished by a variety of other characteristics as well; eg. chromatographic behaviour, serological specificity, differential solubility and catalytic properties. More than 30 enzymes have been shown to exist in multiple forms in both plants and animals, in unicellular micro-organisms as well as multicellular species. Extensive studies have been carried out on lactic dehydrogenase (LDH) in tissues of various species and I shall limit myself to a discussion of LDH isozymes and their physiological and clinical significance.

One of the simplest and most direct techniques available for demonstrating this heterogeneity is the fractionation of the enzyme preparation by starch gel electrophoresis. The principle of the method as described by Markert and Moller (1959) is shown in figure 8. The homogenate of the tissue under study is inserted into a slot made in the starch gel and a direct current passed through the gel. LDH will migrate as 5 distinct fractions, 4 towards the anode and one towards the cathode. The resolution of the proteins is sharper on the inside of the gel and therefore the block is cut longitudinally in half when the run is complete.

The method of localising the isoenzyme on the cut surface has to be sufficiently sensitive to show up minute quantities of protein, and also sufficiently specific to show only protein with LDH activity. This is achieved by using a histo-chemical procedure. The cut surface is incubated with the reactants of the enzyme, lactate and NAD, and the ingredients for developing the histochemical reaction, phenazine methosulphate (PMS) and the dye, nitro-blue tetrazolin (Nitro-BT). The H taken by NAD from lactate is handed over to PMS, which donates it to the dye. Reduced Nitro-BT is a purple, water-insoluble compound and is precipitated on the gel surface at the point where LDH is located. Even a single molecule of the enzyme will be shown up by the dye. Since the molecules of LDH have migrated as discrete zones in the gel, the dye will be deposited in a series of bands, the size and intensity of each band varying directly with the concentration of the enzyme. The technique is extremely sensitive and will detect less than 0.03 μg of enzyme in the LDH bands.

Five different bands have been obtained with LDH of human tissues, designated LDH_1, LDH_2, LDH_3, LDH_4 and LDH_5, LDH_1 being the fastest moving component and nearest the anode, LDH_5 being nearest the cathode. More than five fractions may be demonstrated by using UV light to show up sources of enzyme activity. LDH-1, LDH-2 and LDH-3 predominate in adult heart and kidney, while in muscle and liver the dominant band is LDH-5, and LDH-3 in spleen. Each tissue has its own unique pattern, but all contain 5 isozymes. The testis is an important exception, a sixth isozyme appearing in the post-pubertal testis, specific for this particular tissue.

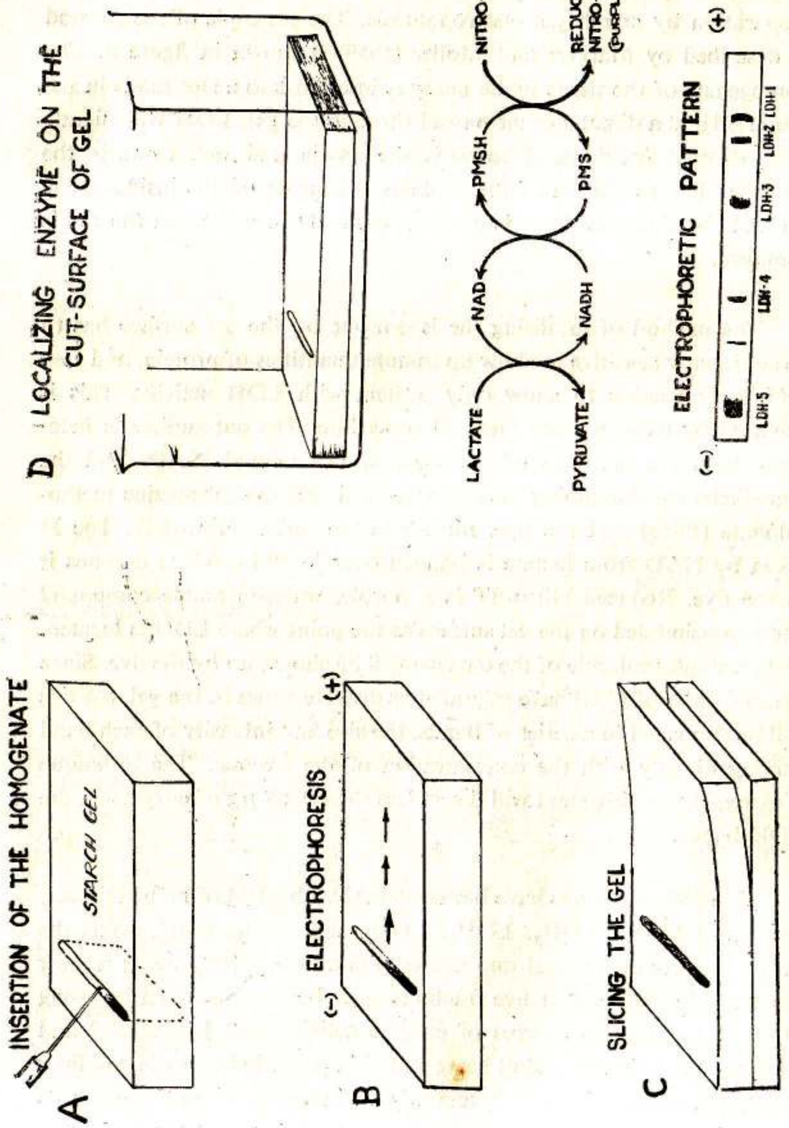


Fig. 8. A 'diagrammatic' outline of the procedure for demonstrating the molecular heterogeneity of a single enzyme by starch gel electrophoresis.

Each LDH isozyme has been shown to be built up of polypeptide chains assembled at random from 2 polypeptide sub-units, A and B (Markert, 1965). The polypeptide composition of each isozyme can be represented as follows:

LDH-1	BBBB	(A_0B_4)
LDH-2	ABBB	(A_1B_3)
LDH-3	AABB	(A_2B_2)
LDH-4	AAAB	(A_3B_1)
LDH-5	AAAA	(A_4B_0)

Due to the random joining together of the sub-units A and B five different molecular types can be generated, and the isozymic composition of any cell will depend on the relative rates of synthesis of each polypeptide. The synthesis of the sub-units is controlled by two separate non-allelic genes. LDH variants are inherited as autosomal co-dominant characteristics.

In the case of the LDH isozymes, therefore, the molecular sizes of the five components are not likely to be very different from one another. In other cases the different isoenzymes may also be made up of several tub-units, but the total number of such sub-units may be different in she different components. The components would then be of different molecular sizes. Another cause of such molecular differences may lie in the non-protein moiety which is present in many enzyme molecules. Certain enzymes, for example, contain sialic acid residues, and differences in the number of these could certainly lead to differences in electrophoretic mobility. No doubt other causes for such molecular differences will be found, and it is also likely that more than one type of molecular difference could be significant in a single family of isozymes.

Functional Significance

Why should there be more than one form of enzyme, each catalysing the same reaction?

One reason seems to be that the catalytic properties of the enzyme has to be suited to the metabolic requirements of a particular tissue. Take, for instance, skeletal muscle and heart muscle. Skeletal muscle LDH contains mainly A polypeptides, which have been shown to be inhibited by only very high concentrations of pyruvate. Therefore the reaction

Glucose ——→ pyruvate ——→ lactate

can proceed to the right. As the lactate is removed by the blood stream, more and more glucose can break down to pyruvate to provide energy for muscle contraction, and the process could be anaerobic.

In contrast, the major isoenzyme in heart muscle contains mainly B polypeptides, which are strongly inhibited by even low concentrations of pyruvate. Therefore pyruvate is not converted to lactate but is metabolised in the TCA cycle. In heart muscle there is little need for anaerobic energy. The different isoenzymes could therefore account for the different types of respiration present in these tissue.

Multiplicity in the form of an enzyme may represent one of the mechanisms which has evolved for certain types of metabolic regulation. Recent studies have shown that the accumulation of an end-product of a biosynthetic pathway may regulate this pathway in one of two ways:

1. by inhibiting the enzymes involved in one or more reactions of this pathway—feed-back inhibition.

2. by inhibiting the synthesis of these enzymes—repression.

The activity of the whole pathway will cease when either of these processes occurs. In certain reactions, however, such regulation by end-products cannot provide the specificity that is essential for metabolic control.

Take, for instance, the following sequence:

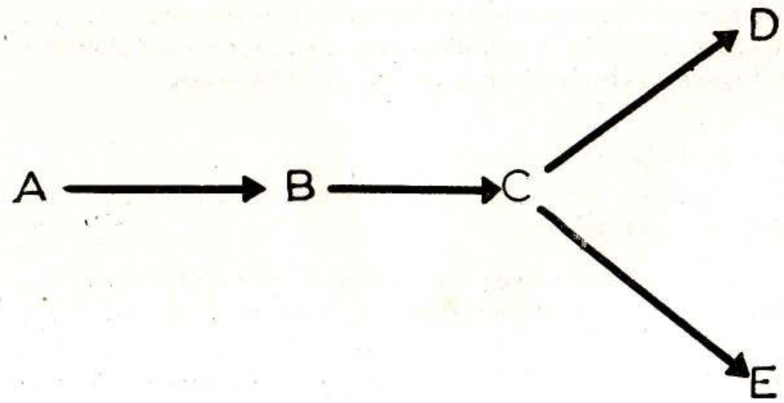


Fig. E

Steps A to C are common to the synthesis of both D and E. Excessive accumulation of D could lead to an indiscriminate inhibition of synthesis of both D and E. If, on the other hand, there were two enzymes catalysing the step B to C, similar in their substrate specificity but different in their susceptibility to end-product regulation by D or E, then there could be independent regulation of two pathways.

This situation has been found in the microorganism, *E. Coli*, in which the enzyme, aspartokinase, catalyses the first step of the following reaction sequence:

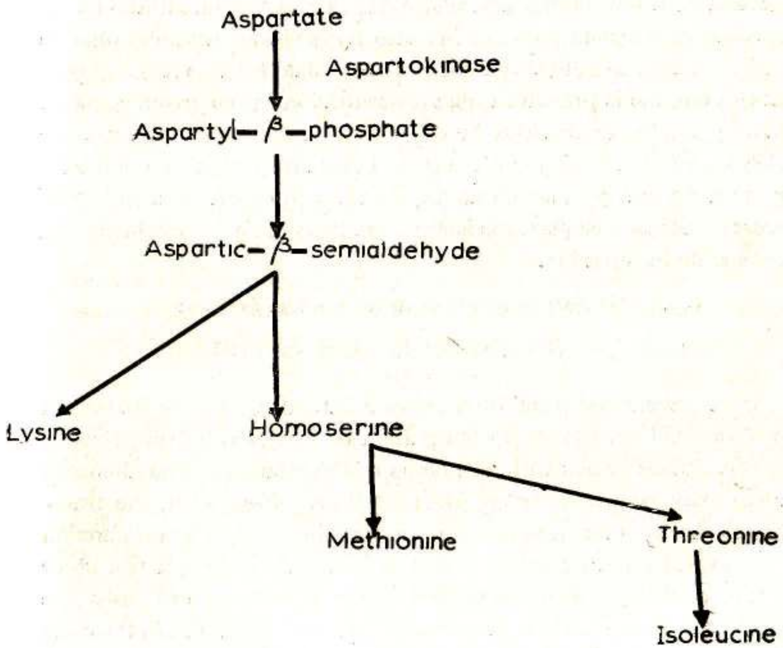


Fig. F

Aspartokinase exists as 3 isozymes, one of which is inhibited by lysine, another by threonine and a third by homoserine (Stadtman, Cohen & LeBras, 1961).

When E. Coli are grown in a medium containing lysine, only one isozyme is inhibited, and the other two continue to function, and threonine and methionine are synthesised. If lysine inhibited all three isozymes, the effect could be lethal and the organism would die. For its survial, therefore, it is necessary to make three molecular forms of a single enzyme. It is likely that isozymes will be shown to function similarly in multicellular organisms as well.

Clinical Applications

The estimation of enzyme activity in blood serum and other body fluids has been used as a diagnostic aid for many years, but the information obtained depends largely on the distribution of the enzyme in tissues. Enzymes like acid and alkaline phosphatases and amylase are concentrated in a few tissues and elevations in serum concentration may have diagnostic significance. For instance, a high serum acid phosphatase activity is taken to indicate cancer of the prostate because it is known that this enzyme is present in high concentration in the prostate, and in relatively low concentrations in other tissues. But most enzymes are widely distributed throughout the body in relatively high concentration and an abnormality in serum activity can accompany a wide variety of illnesses. In these instances the isozyme patterns in tissues might furnish more specific information.

e.g. LDH normal serum is distributed as follows:

LDH-2 > LDH-1 > LDH-3 > LDH-4 > LDH-5

In a patient suffering from myocardial infarction, the pattern in the serum will correspond to the pattern of isozymes in heart muscle, and this change occurs within 24 hours of the infarction. The abnormal pattern may persist for more than 24 weeks, even when the transaminase levels have returned to normal limits. A fresh infarction superimposed on a myocardium which is already damaged will show the abnormal serum isozyme pattern, which will thus be of assistance in answering the question as to whether a patient with a pain in the chest who has had a previous infarction is now suffering from a second attack (Latner, 1964).

Another area in which the study of isozymes might provide useful information is in the study of muscular dystrophies (Kaplan & Cahn, 1962). For example, in the chick embryo LDH-1 predominates, but in adult birds the main fraction is LDH-5, so that during development there is a shift in the synthesis of the polypeptide sub-units, from A type to the B variety. In adult chickens with a form of muscular dystrophy the shift from LDH-1 to LDH-5 fails to occur. A similar abnormality

has been reported in human dystrophic muscles. The basic defect, therefore, appears to be a block in the action of genes controlling the synthesis of polypeptide sub-units. If the block is due to a generalised disturbance in muscle metabolism, it should be possible, by isozymic studies, to determine at what period of development a metabolic abnormality occurs.

A question that arises when considering the anatomical distribution of genetically determined enzyme abnormalities is: How is it that certain inherited metabolic disorders involve some tissues and not others? It may be that the affected enzyme normally exists in several different molecular forms and the abnormality appears only in those tissues in which the synthesis of the major isoenzyme form is controlled by a mutant gene (Zinkham, Blanco and Kupchyk, 1966).

Isozymes thus represent another facet of differences at various levels of biological organization ranging from cells to tissues to species. Recognition of this form of molecular diversity has given new insight into such varied phenomena as the nature of gene action, enzyme structure and gene function, biochemical maturation and the mechanism of the disease process. It is likely that further studies of isozymes will continue to be of theoretical and practical interest to the pathologist and clinician.

LYSOSOMES

We now come to another group of enzymes whose existence has been known for some time, but whose existence together in specific cellular compartments has been demonstrated only recently. The enzymes are acid hydrolases which bring about hydrolysis of a variety of cellular components at a relatively acid pH.

These hydrolases have been shown to be contained in small cytoplasmic bodies, called "lysosomes" by De Duve and his colleagues (1955) who first isolated them. These lysosomes are bounded by a single outer membrane which prevents the enzymes gaining access to substrates within the cell. Damage to the membrane could release enzymes in their active form. De Duve called them "suicide bags" because the enzymes contained in them are a potential danger to the life of the cell.

Several chemical and physical agents break lysosomes. There are also agents which stabilise them against disruption (Gordis, 1966). Many of these agents are of interest also because of their pharmacological or pathological effects on man.

Since 1955 an enormous amount of evidence has become available which makes it clear that lysosomes are involved in a very wide variety of cellular phenomena. A great deal of information is available about the properties and activities of these cytoplasmic bodies, but little is known of their exact function in a normal cell.

The activities of lysosomes can be grouped under 4 main headings:

1. Autolysis of dead cells

This was the first function to be attributed to lysosomes. The enzymes were believed to be released into the cell, bringing about cell death. The best example is the action of streptolysin-S. This toxin is capable of dissolving the lysosomal membrane, resulting in the discharge of its contents into the cytoplasm, liquefaction of the cytoplasm and cell death. The concept of a suicide bag, however, has to be abandoned. There is increasing evidence that cells are seldom, if ever, killed by their own hydrolases. These enzymes merely serve to digest the corpse after the cell has met its death from other causes.

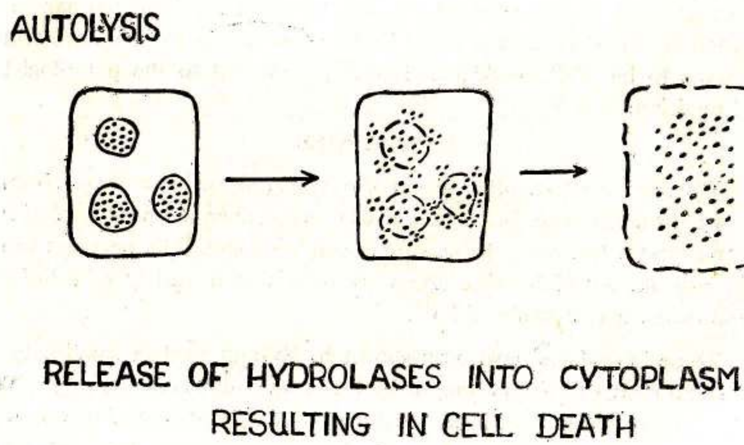


Fig. 9. Autolysis of cells by lysosomal anzymes.

2. Destruction of constituents of living cells or autophagy

Lysosomes digest components of the cell such as mitochondria. The particular component is walled off from the rest of the cell, forming the autophagic vocuole. Acid hydrolases are discharged into it and the component is digested. This process occurs in all cells, but is much exaggerated under certain pathological conditions.

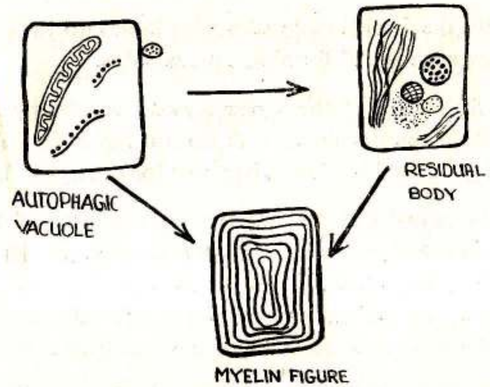


Fig. 10. Destruction of components of a cell by lysosomal enzymes.

Autophagic vacuoles appear whenever a cell has to sacrifice a portion of its own cytoplasm in response to fasting, anoxia, or during active catabolism—as in liver under the influence of glucagon.

Autophagy must therefore be considered an important cell function.

3. Destruction of material introduced into the cell

The best examples are leucocytes and macrophages. The cytoplasm of the cell flows round the foreign material and engulfs it. A phagosome is thus formed. Lysosomes are arranged round it, fuse with it, and the hydrolases attempt to digest the foreign matter.

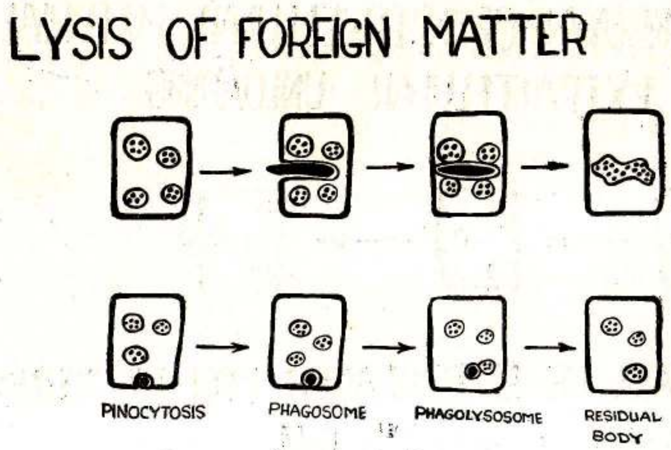


Fig. 11. Upper diagrams illustrate the digestion of engulfed material by lysosomal enzymes. Lower diagrams illustrate the digestion of material entering cell from environment.

In other cells, the foreign material pushes itself into the cells, invaginating the cell membrane and forming a phagosome.

During the formation of these phagolysosomes the hydrolases are still enclosed within the membrane and do not harm the cell. The cell appears to be in good health after its bacterial (or other) meal.

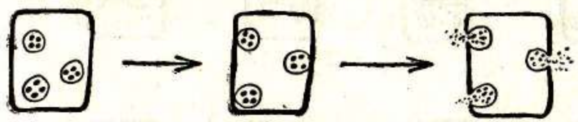
Examples: in amphibian metamorphosis, elements of tail parenchyma are seen in the digestive vacuoles of macrophages. During uterine involution macprophages invade the tissue bringing the hydrolases. In the normal uterus, the fragility of the endometrial lysosomal membrane changes at different stages of the menstrual cycle.

In thyroid cells, stimulated by thyrotropin, the thyroglobulin is taken up by the cell by pinocytosis, and digested by proteases in the lysosomes to release the hormone. Here are cells which synthesise a protein, thyroglobulin, which is stored outside the cells and subsequently digested by hydrolysis in the same cells. The need for separate compartments for storing these hydrolases becomes obvious.

4. Breakdown of intercellular material

Certain agents activate the lysosomes and cause the cell to release into its environment an excessive amount of acid hydrolases, which can degrade the intercellular substance.

BREAKDOWN OF INTERCELLULAR MATERIAL
BY EXTRACELLULAR UNLOADING



RELEASE OF HYDROLASES FOR DIGESTING
MATERIAL OUTSIDE THE CELL

Fig. 12. Digestion of intercellular substance by lysosomal enzymes discharged outside the cell.

e.g. In cartilage and bone cells treated with vitamin A. The vitamin disrupts the lysosomes, acting directly on these particles, releasing the enzymes, which digest the matrix and brings about cartilage and bone resorption (Thomas, 1965).

The final fate of the digested products in autophagic vacuoles or in phagolysosomes is not clear. In protozoa the normal fate of residual contents of food vacuoles is elimination into the exterior by "defaecation", probably by exocytosis, which is the reverse of endo- or pinocytosis. In mammalian cells connected with an excretory outlet, such cellular defecataion may take place. For instance, bile contains lysosomal enzymes. Some of the products of digestion can pass into the surrounding cytoplasm through the phago-lysosomal membrane. Or, as occurs in the case of phagocytes the whole cell may be ejected from the organism. Loaded RE cells are eliminated via the pulmonary alveolae. Pus formation represents another mechanism for achieving the same result. In general, however, the cells of higher organisms appear to suffer from "chronic constipation" and progressive lysosomal engorgement may be held responsible for many pathological disorders. Hyaline droplets found in kidney tubules in various kinds of nephroses is an illustration of such a disorder. Excessive passage of normal plasma proteins in the glomerular ultra-filtrate, or the production of proteins of low molecular weight, as in multiple myelomatosis, may be the primary causal factor. In general we may expect to encounter such lysosomal engorgement in any of the numerous conditions when endocytosis brings into the lysosomes more material per unit time than the hydrolases present can cope with. Normal lysosomal function will be impaired, disrupting cellular organization, which may favour cellular autophagy and lead to lysis of the cells due to rupture of the particles (de Duve and Wattiaux, 1966).

These examples demonstrate the function of the lysosomes in various pathological conditions. We know little of their function in normal cells. The evidence indicates that their main function in the interaction of the organism with the outside world is one of defence. They are also concerned with the normal turn-over both of cell organelles and of organic compounds required by tissues.

Multicellular life seems to depend, to a very large extent, for its maintenance and harmony, on the continuous destruction of the products of its own industry.

Lysosomes and Carcinogenesis

Lysosomes have been implicated in the pathogenesis of human diseases in several ways (Weissmann, 1965; B.M.J. 1966; Gordis, 1966, But the most remarkable contribution towards the understanding of the disease process made by the study of these particles is in the field of cancer (Allison, 1966).

A malignant change can take place in a wide variety of cell types. An even greater variety of carcinogenic agents are known. Any theory that attempts to explain the causation of cancer must take these two factors into consideration.

The change from a normal to a malignant cell can be looked upon as a somatic mutation. The progeny cell inherits the potential for abnormal growth from the parent cell. It is therefore conceivable that some change in the genetic material has taken place during the malignant change. The mutation affects the capacity of the cell to respond to mechanisms that control growth, for the cancer cell is one of uncontrolled growth. But it does not, however, affect the capacity of the cell to divide. The mutation is therefore most likely to be one of gene deletion. The most likely mechanism for producing a deletion of genetic material is the release of an enzyme capable of attacking DNA. All cells contain in their lysosomes the enzyme DNA-ase which is capable of breaking both strands of a double helix of DNA.

The hypothesis is therefore, as follows:

If lysosomal enzymes are released and can gain access to genetic material without, at the same time, impairing the capacity of the cell to divide, they might produce genetic changes which result in a particular variety of somatic mutations which lead to cancerous growth.

How does this hypothesis stand up to available experimental data?

There are three main types of cacinogenes—chemical, physical and viral. The effect of all these on lysosomes have been tested.

Chemical carcinogens have been shown to affect lysosomes. Many of these are taken up by lysosomes. Co-carcinogens—compounds which by themselves have little oncogenic capacity, but which greatly magnify the effect of small doses of hydrocarbon carcinogens, all increase the permeability of lysosomal membranes.

Physical agents like UV radiation and ionizing radiation can bring about release of lysosomal enzymes.

Viruses can also affect lysosomes of the host cell. A virus enters a cell by pinocytosis. Lysosomal enzymes digest away its protein covering, releasing viral DNA, which begins to multiply. During replication of DNA the lysosomal membrane may be damaged or show changes in permeability. Infections with viruses are known to produce chromosomal abnormalities. Some viruses are known to transform normal cells into cancer cells, and in these, chromosomal aberrations are known to occur.

Therefore, there is sufficient evidence to make lysosomal enzyme release or activation at least a possible candidate for the common mechanisms in cells that are set in motion by diverse carcinogenic agents.

Different cell types have been studied for changes after selective activation of lysosomes, and preliminary results indicate that cells with abnormal growth patterns are produced.

The lysosomal hypothesis of carcinogenesis, however, is still speculative, but significant advances can be expected in the near future.

Conclusion

I hope that the examples I have taken are sufficient to prove the need for a more biochemical approach to the study of pathology. It is with pleasure that one reads of a progressive pathologist, Sir Roy Cameron (1956) who, being dissatisfied and often discouraged by a mere morphological outlook on cellular pathology, has turned to recent biochemical and biophysical techniques for illumination in his difficulties and has so come down to a study of intracellular lesions. A similar point of view has been put forward by Dawkins and Rees (1959).

The partnership between pathology and biochemistry, which has been so evident in recent years, appears destined to persist.

References

ALLISON, A.C. (1966). The Possible Role of Lysosomes in Carcinogenesis. Proc. Roy. Soc. Med. **59**, 868.

BAGLIONI, C. (1963). Correlations between Genetics & Chemistry of Human Haemoglobins. In "Molecular Genetics", Part 1, p. 405. Ed. J.H. Taylor. London: Academic Press.

BERGSTRAND, A., ELIASSON, N.A., HAMMARSTEN, E., NORBERG, B., REICHARD, P. & VON UBISCH, N. (1948). Cold Srping Harbor Symp. Quant. Biol. **13**, 22.

British Medical Journal (1966). Lysosomes. Brit. Med. J. **i**, 495.

CAMERON, G.R. (1956). New Pathways in Cellular Pathology. London: Edwin Arnold Ltd.

DAWKINS, M.J.R. & REES, K.R. (1959). A Biochemical Approach to Pathology. London: Edwin Arnold Ltd.

DE DUVE, C., PRESSMAN, B.C., GIANETTO, R., WATTIAUX, R. & APPLEMANS, F. (1955). Tissue Fractionation Studies. Biochem. J. **60**, 604.

DE DUVE, C. & WATTIAUX, R. (1966). Lysosomes. An. Rev. Physiol. **28**, 435.

GORDIS, L. (1966). Lysosomes & Disease. J. PEDIAT, **68**, 638.

HARRIS, H. (1965). The Ribonucleic Acids in the Nucleus and Cytoplasm of Animal Cells. Endeavour **24**, (91), 50.

KAPLAN, N.O. & CAHN, R.D. (1962). Lactic dehydrogenases and muscular dystrophy in the chicken. Proc. Nat. Acad. Sci. **48**, 2127.

LATNER, A.L. (1964). Isoenzymes .In "Recent Advances in Clinical Pathology", Series iv, p 70. Ed. S.C. DYKE. London: Churchill Ltd.

LIEBECQ, C. & PETERS, R.A. (1949). Toxicity of fluoro-acetate and the tricarboxylic acid cycle. Biochem. Biophys. Acta **3**, 215.

MARKERT, C.L. (1964). Developmental Genetics. Harvey Lectures **59**, 186.

MARKERT, C.L. & MOLLER, F. (1959). Multiple forms of enzymes: tissue, ontogentic and species specific patterns. Proc. Nat. Acad. Sci. **45**, 753.

NIRENBERG, M.W. & JONES, O.W., Jnr. (1963). Current Status of the RNA Code. In "Informational Macro-molecules", p. 451. Eds. H.J. VOGEL, V. BRYSON & J.O. LAMPEN. London: Academic Press.

PETERS, R.A. (1936). Biochemical Lesion in Vitamin B_1 deficiency. Lancet **i**, 1165.

PETERS, R.A. (1963). Biochemical Lesions and Lethal Synthesis. London: Pergamon Press.

REED, L.J. (1953). Metabolic Functions of Thiamine and Lipoic acid. Physiol. Rev. **33**, 544.

STADTMAN, E.R., COHEN, G.N. & LE BRAS, C. (1961). Feed back inhibition and repression of aspartokinase activity in Escherichia Coli. Ann. N.Y. Acad. Sci. **94**, 952.

STOCKEN, L.A. & THOMPSON, R.H.S. (1946). British Anti-lewisite. 2. Dithiol Compounds and Antidotes for Arsenic. Biochem. J. **40**, 535.

THOMAS, L. (1965). Vitamin A and Lysosomes. In "The Inflammatory Process", p. 451. Eds. B.W. ZWEIFACH, L. GRANT & R.T. MCCLUSKY. London: Academic Press.

WEISSMANN, G. (1965). Lysosomes in Medicine, 1 & 11. New. Eng. J. Med. **273**, 1084, 1143.

WIKRAMANAYAKE, T.W., HEAGY, F.C. & MUNRO, H.N. (1953). The Effect of the level of energy intake on the metabolism of ribonucleic acid and phospholipid in different parts of the liver cell. Biochem. Biophys. Acta, **11**, 126.

ZINKHAM, W.H., BLANCO, A. & KUPCHYK, L. (1966). Isozymes: Biological and clinical significance. Pediatrics, **37**, 120.

SECTION B—AGRICULTURE AND FORESTRY

Presidential Address

A CENTURY OF PLANT DISEASE INVESTIGATION IN CEYLON

by

D. V. W. ABEYGUNAWARDENA

Mr. President, Ladies and Gentlemen,

As far back as 1798, Thomas Malthus in his classical essay on the *Principle of Population* projected the inevitability of poverty and famine because population increased by geometric ratio whereas food supplies increased *only* by arithmetic ratio. This has been amply demonstrated today in that half the world is confronted with hunger while certain countries in our neighbourhood are continually threatened with starvation and famine. Increased food production, therefore, will constitute the greatest challenge to mankind in the half century yet to come. Man's greatest enemy in increasing food supplies is plant disease, the study of which is both my livelihood and hobby and will therefore form the main theme of this address today.

The title "A Century of Plant Disease Investigation in Ceylon", however, requires some explanation. It was a century ago that the first plant disease of importance in Ceylon ravaged the then flourishing coffee plantations in the central hills and thus heralded the birth of plant disease investigation as an applied science in Ceylon or for that matter laid the very foundation of tropical plant pathology. Since the coffee era plant disease has increased in occurrence and severity and is today a formidable threat to food production. This, I feel, is sufficient justification, though not on high philosophic grounds, for the choice of this subject for an address today.

Increase of Disease

Let me at the outset introduce you to the subject in a general sense. Plant disease is older than man himself but the greatest danger from plant pathogens arose when agriculture started. Agriculture or the growing of crops by man was the first interference with the ecologic balance of naturally occurring plant communities. Interference with the ecologic balance brought about by cultivating or grouping together a large number of similar plants has resulted in an ideal biological climate for the persistence and spread of pathogens. The situation has been aggravated today partly by the high cultural regimes designed to maximise yields per acre, a feature characteristic of modern horticulture and agriculture, and partly by the absence of sufficiently long crop rotations or fallow periods necessitated by the increased pressure for arable land. These practices greatly favour the pathogen by increasing its infection potential in the cultivated area.

Early Thoughts on Plant Disease

In the ancient classics the causes of plant disease have been attributed to the evil influences of the stars or to Divine displeasure rather than to biological agencies. During the Roman period, for example, the festival of Rubigalia was celebrated on the 24th of April of each year to placate the rust Gods Rubigus and Rubigo who were thought to be vested with the supernatural power of regulating the annual epidemics of Rust disease attacking corn. Even today some farmers treat plant disease epidemics with a superstitious fatalism attributing them to the evil eyes or to the evil mouth of an angry neighbour or to Divine displeasure. A fascinating contrast to this belief is found in the False Smut disease of paddy, also called "Rukmal Pippeema", the appearance of which during the grain filling phase of the crop is hailed by our farmers and is thought to signal a forthcoming bumper harvest.

The Notorious Potato Murrain

A quarter of a century prior to the arrival of the Coffee Rust disease in Ceylon, the notorious Irish famine had already illustrated the grim effects following crop disease epidemics. The microscopic fungus equipped with a powerful macerating enzyme complex rotted the potato crop in Ireland practically overnight where potato was the staple food crop of the peasant population. This Irish potato murrain virtually halved the

population of Ireland following death due to famine and due to mass emigration to other lands.

This was the tragic illustration of a plant disease epidemic in eighteen forties.

The Coffee Crash in Ceylon

While *Phytophthora* was taking an annual toll of the potato crop in temperate countries, *Hemileia* was stripping the coffee trees of their foliage in the central hills of Ceylon. The malady first broke out on a new estate at Madulsima from where it spread with lightning speed over the various coffee-growing districts attacking both young and old trees with almost equal severity. Repeated onslaughts by this disease exhausted the coffee trees and resulted in a rapid decline in their vigour and crop bearing capacity. The average annual yield which was in the order of 4.5 cwt. per acre at the height of prosperity of the coffee industry declined to only 2 cwt. per acre in 1878. Since the appearance of the disease in Ceylon the enterprise suffered from 120-150 million rupees in crops alone.

The investigation of the coffee disease in Ceylon was begun by Daniel Morris and continued by Marshall Ward, a young botanist from Cambridge, but they were both late and were in time only to perform the post mortem of the industry rather than recover it from the malady. Their pioneer efforts, nevertheless, stand pre-eminent in the annals of plant pathology for this alone opened the first chapter on plant disease investigation in the tropics. Their task was difficult and had to wade through superstition and fables invented by the people. One such fable, for example, was that coffee rats came out of the forest once in seven years when the *nillu* tree died and these rats caused the coffee disease.

The coffee disease epidemic of 1867 had far-reaching results; it led to the abandonment of coffee-growing in the central hills and bankrupted many coffee-growers; it accelerated diversification of agriculture and re-assured the economy of the country, and finally perhaps the most important to the advancement of agriculture, it hastened scientific investigation of plant disease control and generally speaking of agriculture in Ceylon.

The Second Phase of Development

The second phase in plant disease investigation followed the general pattern of development of mycology rather than of applied plant pathology. Disease problems on tea, rubber, coconut and cacao were few; the crops flourished on newly opened virgin soil where an occasional death of a plant due to root disease was perhaps the most serious complaint. The remedy was cut and dry, or more precisely cut and burn, a prescription that raised a laugh even today at meetings of students and planters, not realizing of course, the importance of eliminating the source of infection in root disease control.

Emphasis centred around descriptive and taxonomic phases of fungi, the study of which led to the identification of 2182 fungi, 60 per cent of which have been described as new Ceylon species. Petch, in particular, took to mycology as his hobby and his intimate knowledge of Ceylon fungi and their fascinating associations with the two major plantation crops in the island have been summarised in three books and a long succession of scientific papers.

Until the year 1936, 885 diseases affecting 340 host plants were diagnosed. Theories were developed to explain the causation of disease and the phenomenon of host predisposition. Small, for instance, claimed that the universally recognized root disease fungi *Poria*, *Fomes* and *Rosellinia* were harmless and that all root diseases were caused only by *Rhizoctonia bataticola*, a fungus notoriously harmless and thrives saprophytically in tropical soils. Small's claim triggered a prolonged philosophic argument between him and his fellow mycologists working in Ceylon, which now provides a week's bedtime reading to those fascinated by philosophic opinions rather than experimental facts.

Winds of Change in Applied Disease Control

Park and Chandraratne (1940a) introduced field experimental analysis in studies of epidemiology and crop disease control and thereby gave an applied twist to the subject. Their work included the discovery of a wilt-resistant variety of brinjal from Raitalawala in South Matale and is still claimed as a formidable and steady source of resistance by plant breeders in other parts of the world. An improved edition of this variety designated S.M. 164 combining both wilt resistance and superior fruit quality is now available to vegetable growers who could raise prolific crops even on Wilt infested soil. They demonstrated (Park and Chandraratne, 1940b) the feasibility of controlling the Frog Eye disease of tobacco by a systematic spray program but due to the primitive state of peasant agriculture at the time this method of plant disease control had little attraction. The method of diagnosis and control of crop diseases known at the time were monographed by Park and Chandraratne, under the title "Diseases of Village Crops in Ceylon".

The Dynamic Phase

The more dynamic phase in the development of plant pathology originated after the second world war and marked the introduction of intensive standards of manuring and cultivation, and the increasing use of pure-line and clonal varieties in modern horticulture and agriculture. Intensive cultivation of agricultural crops intended to maximise per acre yields and to satisfy the consumer with a uniform produce, therefore caused the increased appearance of explosive epidemics and spread of disease with greater speed. The days of ivory tower in plant pathological research had passed and practical remedies were demanded by the agriculturist.

The first disease that scared the agriculturist and the politician in the post-years was Blister Blight of tea, the arrival of which in 1946 was thought to be a grave threat to the tea industry. The misfortunes of European planters with the coffee crash and the scares created with a similar threat to the mainstay of our economy stimulated thinking among prophets of doom, writers of letters to newspaper-editors and finally but silently among the plant pathologists working on this crop. The causal fungus *Exobasidium vexans* was however less vicious and incapable of defoliating the tea plant unlike what *Hemileia* did to coffee. It was, however, damaging the most vital parts of the tea bush, the two leaves and the bud used in the manufacture of tea.

Pioneer work of Gadd and Loos, outlined three main forms of control applicable to Blister Blight in Ceylon as firstly, protection of susceptible crops with copper fungicides, secondly modification of agricultural practices and thirdly, establishment of blister resistant clones.

Meanwhile Peiris (1953a, 1953b, 1960) recognized the frequent appearance of virus disease in cultivated crops and signalled their potential danger in intensive agriculture. Virus diseases were noticed on cacao, chilli, citrus, papaw, tobacco and other vegetable and fruit plants. He outlined preventive measures based on the knowledge available at the time.

Cacao Virus in the Dumbara Valley

The cacao plantations in the Dumbara Valley, one-time thought to produce the finest quality cocoa in the world, were struck by the deadly Swollen Shoot virus complex in 1955. This same disease attacked cacao in the African continent, and in Ghana alone 63 million infected cacao trees were eradicated in 10 years, a campaign spearheaded by the Government the cost of compensation of which to farmers being over Rs. 91 million. The disease occurs sporadically in the Dumbara Valley and is largely confined to the vein-clearing and vein-flecking phases rather than the more hazardous swollen-shoot phase.

A *cordon sanitaire* of the disease stricken Dumbara Valley effectively arrested the spread of the virus to other cacao-growing areas in the country by preventing the flow of infected planting material from the infected zone to disease-free areas. A planned programme of replanting of cacao in the infected zone has been recommended as the best means of eliminating the virus from the Dumbara Valley.

Chilli Virus Complex

Imports of chilli in recent times have cost the country over Rs. 40 million per annum in foreign exchange. This crop is attacked by a fatal virus complex, and lately virus diseases have practically halved the potential harvest in Ceylon and have often disappointed farmers who ventured out to grow this crop on an extensive scale.

Peiris (1953b) resolved chilli leaf curl complex as induced by mites, thrips and the leaf-curl virus. While insecticidal sprays provided an effective answer in the control of mite and thrip induced disease, adequate control measures were not available for the leaf curl virus.

Our recent studies have shed brighter light on the etiology of the virus complex while widely scattered field surveys coupled with intensive epidemiology studies of growers crops in the predominent chilli-growing districts of Chilaw, Puttalam and Jaffna have revealed

(i) that the mosaic viruses constitute the major pathological problem of chilli both in the nursery and in the transplanted crop,

(ii) that there was an explosive epidemic of the mosaic virus disease immediately following transplanting, often reaching 100 per cent infection of the crop even before the first pick was gathered, and

(iii) that the leaf curl virus is a minor problem, its spread within a crop being slow and progressive except in localities where chilli is grown round the year, uninterrupted by seasonal change or crop rotation.

By an intensive laboratory study of physical and biological properties, the viruses comprising the mosaic complex were characterized as the Tobacco Mosaic Virus and an atypical strain of the Cucumber Mosaic Virus.

In a screening of introduced and local chilli varieties, resistance to Tobacco Mosaic Virus was detected in the variety P.I. 159254 while a high degree of tolerance to Cucumber Mosaic Virus was exhibited by the Maha Illuppalama Hybrid and a variety originating from Matara. These varieties have now been recommended as sources of resistance or tolerance worthy of exploitation in breeding new varieties of chilli for cultivation under our conditions.

Disease, as a Limiting Factor to Potato Production

Potato, another popular subsidiary food crop consuming our foreign exchange is highly temperamental in the tropics and is liable to attract more than 50 different diseases. The establishment of potato cultivation in Ceylon and abroad, has in fact, been a continuous struggle against disease.

Lorenz, an unofficial magistrate from Morawak Korale was the first to demonstrate over a hundred years ago, the cultivability of Irish potato in Ceylon. His second experiment, however, met with utter failure—instead of normal size tubers, he harvested degenerated, small tubers much like marbles. Since then several attempts have been made to establish the crop in the cooler altitudes of the country but growers have been demoralised each time due to destruction of their crops by disease.

There are 3 principal disease problems we have to grapple with in Ceylon. First and the most harmful is Bacterial Wilt caused by a bacterium that inhabits tropical soils; secondly Late Blight, the cause of the notorious Irish murrain; the fungus responsible being endemic in moist areas of the country and capable of quickly producing new physiologic or more virulent strains; and lastly, the virus diseases, the cause of degeneration or "running out" of planting stocks producing marble size potatoes like what Lorenz gathered in his second experiment.

Bacterial Wilt is widely prevalent in tropical countries, and has made potato cultivation impossible in parts of Australia, India, and the U.S.A. In our work we have mapped out the distribution of Bacterial Wilt in the potential potato-growing areas of the hill country (Abeygunawardena and Wijesooriya, 1960a). This study demonstrated that the incidence of Bacterial Wilt was refreshingly low in the higher cooler altitudes and was virtually absent over 6000 ft. elevation enabling the production of wilt-free seed potatoes at this elevation; that the incidence of Wilt was relatively less in rice fields than in highland plots, a finding that led to the concentration of commercial potato-growing in rotation with paddy in paddy-fields. Bacterial Wilt or Wilt as the farmers call it, is now a word that depresses the spirits of potato growers in the Uva Province. The fear is based on their experience that considerable losses can result from this disease and that no really efficient method of control is yet available.

In recent studies more efficient chemicals and spray schedules have been demonstrated for the control of Late Blight (Abeygunawardena and Wijesooriya, 1960b; Peiris and de Zilva, 1954). This was especially necessary in the cool moist areas of Nuwara Eliya, Ambawela and Bopatalawa because of the endemism of the disease and the generally favourable local environment for the development of epidemics in these areas. A closer insight into the varietal reaction to disease illustrated the development of new physiologic races or biotypes of the pathogen in the Nuwara Eliya area, a phenomenon which has led to the successive breakdown in blight resistance of several potato varieties recommended for cultivation. Also, an exhaustive analysis of the distribution of rainfall and fluctuation in atmospheric humidity and temperature led to the establishment of climagrams defining the different growing seasons to escape blight epidemics in the two major climatic zones, the up-country wet zone and the up-country dry zone (Abeygunawardena and Balasooriya, 1961).

Our experiments show that virus diseases do not present a problem in seed potato production in the higher altitudes. The low temperatures combined with humid atmosphere and moderate winds in locations like Horton Plains and Pidurutalagala prevented colonization of aphids, the principal vectors of potato virus diseases responsible for quick degeneration of seed stocks. Conditions, therefore being ideal, enabled the local production of seed potatoes which practically halved the cost of seed, a major item of expenditure in the cultivation of this crop.

Decline of Citrus

Various theoretical reasons ranging from variation in climate to poisonous gases produced by modern vehicles were adduced to explain the sudden decline of cirtus trees which had faithfully been bearing succulent fruit for more than a quarter of a century in the Bibile region. Kiely (1957) an Australian pathologist working in Ceylon recognized the similarity of the disease to Quick Decline or Tristeza, a dreaded virus disease of citrus in California, Brazil, Argentina and Australia. In Brazil, for example, this disease has killed more than 7 million citrus trees representing nearly 75 per cent of the plantation.

The word "Tristeza" describes the melancholy appearance of diseased trees, the symptoms of which are profuse chlorosis, stem-pitting, bud-union collapse in grafted plants and sudden wilt of apparently healthy trees, often after bearing an abnormally heavy crop. As the two most efficient vectors responsible for field transmission of this disease are widely distributed throughout the country we have to device methods to live with this virus. Growing of orange on tolerant rootstocks and establishment of resistant or tolerant varieties offer scope in this direction.

Abeygunawardena and Herath (1962) reporting the results of experiments involving 54 stock-scion combinations where the plants were artificially inoculated showed Rough Lemon, Sweet Orange and Mandarin as promising rootstocks to circumvent the disease. Some of these more promising graft combinations and seedlings are now under test in different agroclimatic areas of the country.

Mendel (1963) a citriculturist from Israel surveyed the problem in 1963 and expressed that citrus farmers in Ceylon are notoriously efficient fruit-gatherers but are poor fruit-growers. He emphasised the need for establishment of scientifically managed orchards in well-drained deep soils like those found in the Puttalam-Wanathavillu area. Two questions remain yet unanswered. How did citrus plantations, young and old flourish at Bibile prior to the recognition of the disease? and secondly, why do new plantings in already cultivated or even virgin soils decline rapidly? In my opinion the disease complex plays a major role in causing the decline while the other unfavourable soil and cultural factors only hasten the death of infected plants.

Other Destructive Virus Diseases

Destructive virus diseases have also been recognized on economic crops like tobacco, sugarcane, papaw, cowpea and bandakka. Like its close relatives potato and tomato, tobacco is liable to infection by several viruses and is indeed the virologists happy hunting ground. A recent survey of virus diseases infecting the crop in Hanguranketha and Nildandahinna, the two predominant cigarette-tobacco-growing areas, was most revealing. Of the 4760 acres surveyed, 906 acres were infected with Mosaic, 860 with Leaf Curl, 438 with Rosette, 227 with Yellow Net and 21 with Veinal Necrosis. Besides the characteristic patterns on the foliage, these viruses cause a stunting of the crop, often accompanied by leaf distortion, thus making the produce unacceptable to the market.

Despite progress in understanding the virus diseases affecting tobacco far more research is needed to elucidate practical field control measures. The Yellow Net disease has been intensively studied in recent years and is now known to be caused by a persistent virus which is also capable of causing disease on *Nicotiana glutinosa* and *Solanum nigrum* while the common ornamental Bachelor's Button (*Gomphrena globosa*) is found to be a symptomless carrier. Exploitable genetic resistance to Yellow Net has not been encountered in about 40 different tobacco varieties tested. On the basis of these findings the control measures presently recommended are the elimination of virus vectors, especially in the nursery by insecticidal spraying, eradication of alternate host plants and abandoned crops and finally the avoidance of continuous cultivation of tobacco throughout the year.

Papaw Mosaic, also a virus disease, made its appearance in 1952 and practically ousted commercial papain production from the Kurunegala District. Until recently this disease was not known to occur in the wet zone but has now invaded home garden crops in the Colombo District. In the absence of feasible control methods an effort is now being made to eradicate infected plants on a *shramadana* basis before the disease takes a foothold and spreads to other parts of the wet-zone.

In contrast to Papaw Mosaic, there has been a great advance in our knowledge on the Mosaic virus infecting cowpea. Abeygunawardena and Perera (1964) studied the physical properties, vector-virus relationships

and the variety reaction and characterised the virus as a new strain of Cowpea Mosaic. They found that all locally grown cowpea varieties were highly susceptible while others like Arlington, Birmingham, Groit and Victor II contained exploitable gene reservoirs for resistance and recommended their incorporation into the popular varieties as the best means of controlling the virus.

Rice Diseases and their Control

Rice, our staple food crop, is infected by an assortment of diseases. Accurate estimates of crop losses due to disease are not available chiefly because of the complexity of assessment. However, from the information gathered over the years it is clear that the crop loss from disease is in the order of 6 million bushels per annum meaning a monetary loss of Rs. 72 million.

Among the diseases affecting the rice plant, Blast caused by the fungus *Piricularia oryzae* constitutes a major threat to increasing production through the combined use of fertilizer and improved pureline varieties. This disease first causes greyish brown spots on the foliage ultimately killing them and the whole plant.

Measures taken to control Blast are based on the development of blast resistant rice varieties by plant breeding, and on protection of susceptible crops with fungicides. Development of blast resistant rice varieties by plant breeding involved the selection of resistant parental lines from among indigenous rice varieties, and then combining the character for disease resistance with other varieties having economic characters such as high yielding capacity and superior grain quality. Okamoto, a Japanese Pathologist working in Ceylon determined the local variety Murungakayan as highly resistant to Blast, a character that was combined with the Indonesian variety Mas to give the now famous H-4 cultivated throughout the country.

In spite of rosy prospects, breeding of new blast resistant varieties as a means of combating this disease is not the easy road it might seem. Abeygunawardena (1965) showed that resistance of rice varieties "breaks-down" after a period of continuous cultivation, or more precisely a new form of the fungus capable of overcoming resistance appears. The existence in the country of a minimum of 6 biologically different strains or biotypes of the rice blast fungus was demonstrated. It was also shown that foreign blood from varieties like Remadja possessing steadier and more formidable sources of resistance should be exploited in our local rice hybridization programme.

Decline in resistance of improved rice varieties and the increased demand for protection of sophisticated susceptible varieties like samba necessitated the development of efficient means of combating the disease with chemical sprays. Earlier studies revealed the currently used carbamate fungicides as effective in controlling mild epidemics of the disease but our recent experiments have illustrated the extreme efficacy of the organic fungicide Blastin and the antibiotic Kasugamycin under severe epidemic conditions.

Sheath Blight, the second important fungus disease infecting paddy is fast becoming widespread in the ill-drained soils of the wet-zone. The fungus attacks the lower leaf-sheaths causing their premature death and ultimately lowering the yield. A recent survey of the disease in the Kalutara District revealed the occurrence of 9.6 per cent tiller infection and the resulting loss estimated to be 370,000 bushels of paddy per season from this District alone.

Variety resistance or the lazy man's method of control is not known to exist in Ceylon and the only immediately applicable method is by spraying of fungicides. Our recent efforts in this direction convincingly demonstrated that spraying the crop with organo-arsenical fungicide resulted in over 60 per cent increase in grain yield, and that the greatest control is achieved by timing the sprays at effective tillering, end of tillering and booting.

Two nematode diseases of rice have come into prominence in the country in recent times. The first and more important economically is White Tip, an epidemic of which severely affected crops in the dry-zone in 1959. An efficient nematocidal seed treatment was demonstrated by Peiris, a method which has been improved and widely recommended today for nematode disease control in paddy. The second disease is Root Rot, and the nematode responsible is widely distributed in our paddy fields. The disease is complex, the etiology and control of which await more intensive study.

Paddy seed acts as an efficient vehicle for the transport of disease organisms from one district to another. Transmission of disease through seed paddy and consequent outbreak of epidemics have been greatly

reduced by a seed health certification scheme introduced in 1963. Scrutiny of seed-stocks from 1963-65 revealed 39.1% infection with Brown Spot disease, 13.7% with White Tip nematode disease and 8.7% with Foot Rot disease.

Modern Trends in Root Disease Control

The outlook for feasible methods of root disease control in plantation crops is more promising today. Since Napper advocated disinfection of roots infected by the White Root disease in rubber, workers in Ceylon recommended a liberal soil drench with expensive organo-mercury fungicides. Recent work of Peries and co-workers (1959) in the control of this disease in rubber, however, is more revealing. They produced experimental evidence to illustrate that the removal of the food base of the fungus alone gave efficient control of the disease while expensive soil drenches only drained out the now valuable foreign exchange from the country.

Meanwhile Shanmuganathan and colleagues (1965) have proved the feasibility of controlling *Poria* root disease of tea by fumigation of infected soil with methyl bromide, a method that has replaced the classical cut and burn style of controlling root disease.

Regulation as a Weapon of Disease Control

While our struggle against plant diseases that are endemic in Ceylon continues, we have to strengthen our vigilance on the possible introduction of new diseases or new biotypes of plant pathogens into this country. For this purpose a scientific basis has been laid for sensible plant import and quarantine regulations which are embodied in the Plant Protection Ordinance of Ceylon. Our vigilance has been further strengthened by the adoption of the International Plant Quarantine Convention sponsored by the Food and Agricultural Organization of the United Nations. Ceylon is also a member of the South East Asia Plant Protection Convention aimed at preventing the entry of dangerous diseases and pests not found in the South East Asian Region.

How much good these regulations have done is difficult to estimate. We have, for example, successfully kept out of Ceylon the South American Leaf Disease of Rubber which if introduced will wipe out the rubber plantations in this country. Similarly, the entry of dangerous virus diseases of agricultural and horticultural crops has been halted by rigid enforcement of these regulations. If, therefore, an occasional taboo on the importation of some fancied rice seed or grape-vine cutting or the interception of those delicate roses brought into the country by some enthusiastic globe-trotter should appear meaningless, it should be realized that these strictures have been designed to halt the entry of our biological enemies and thereby prevent disaster to our agricultural crops already established in the country.

Need for Further Research

Even at the turn of the century of plant disease investigation in Ceylon, much time should not be devoted to boast about the past achievements. It could be a good lesson in humility to compare what has been accomplished with what might have been. We are yet woefully ignorant about many destructive diseases and unable to find economically feasible methods of controlling them. We are unaware of the cause of the Leaf Scorch disease now threatening our coconut plantations in the Southern Province or the factors responsible for Foxies, a malady that reduces the market quality of cinnamon. We have not found any practical method of controlling Bacterial Wilt of potato, a disease that will continue to dampen our efforts to grow this crop on the hill slopes of Uva. We are, nevertheless, aware that several destructive diseases of crops are lurking in the offing. There is little hope for a universal panacea for plant diseases—each disease will have to be delicately studied in the locality it appears and control measures specific to the plant-disease-environment complex determined. To undertake this continuing battle against plant disease the number of Plant Pathologists in our midst is woefully inadequate.

Application of Existing Knowledge

Although there is a great need for further research on plant disease control in Ceylon, wider application of the existing knowledge should help in our national effort to increase agricultural production. Most farmers fail to recognize disease early enough and bring to the notice of the agricultural extension worker or to the pathologist more for the post mortem rather than for any useful advice. From the practical aspect, intensive farmer training in the recognition and control of plant diseases, convincing demonstration of the recommended methods of control, and strengthening of ~~the supplying~~ needs for disease control are therefore urgently required if we are to achieve any measure of success. In this direction the existing knowledge on plant disease control has been outlined by the author under the title "Diseases of Cultivated Plants in Ceylon" and will be available shortly both in Sinhala and English, a publication sponsored by the Popularisation Committee of this Association.

Future Outlook

Today we know of 1100 diseases infecting 431 plants in Ceylon. During the past few years, we have also recognized the origin of new and more virulent races or biotypes in at least five different pathogens that attack our food crops. The situation at the close of the second century of plant disease investigation in Ceylon is hard to foretell but plant disease is on a forward march and plant pathogens continue to sharpen their weapons of attack to overcome the efforts of agriculturists, plant breeders and plant pathologists. That, I submit in essence, a century of plant disease investigation in Ceylon and the outlook in the second century to come.

References

ABEYGUNAWARDENA, D. V. W. and WIJESOORIYA, R. A. (1960a). Methods of Potato Seed Production in Ceylon. *Trop. Agriculturist* CXVI, 131-137.

——————(1960b). Experiments on the fungicidal control of late blight of potato. *Trop. Agriculturist*, CXVI, 131-137.

——————and BALASOORIYA, I. (1961). Disease hazards in potato cultivation. *Trop. Agriculturist* XCVII, 211-220.

——————and HERATH, H. M. E. (1962). Stock-scion Reaction of Citrus to Quick Decline Disease in Ceylon. *Trop. Agriculturist* CXVIII, 3-13.

——————and PERERA, S. M. D. (1964). Virus disease affecting cowpea in Ceylon. *Trop. Agriculturist* CXX, 181-202 (1965).

——————(1965). Recent Studies on Blast, a disease fatal to rice in Ceylon. Paper presented at the 21st Session of the Ceylon Association for the Advancement of Science.

——————(1966). Recent advances in the control of rice diseases. Paper presented at the Symposium on Rice Production.

KIELY, T. (1957). The decline problem of citrus in the Lower Uva Valley and other areas in Ceylon. Ceylon Government Sessional Paper IX, 1-43.

MENDEL, K. (1963). Report on Citriculture in Ceylon. Ceylon Government Sessional Paper XVII, 1-34.

PARK, M. and CHANDRARATNE, M.F. (1940a).
A variety of Brinjal (*Solanum melongena*) resistant to Bacterial Wilt.
Trop. Agriculturist XCIV, 19-21.

————(1940b).
Recent research in Ceylon on the Frog Eye Disease of cigarette tobacco.
Trop. Agriculturist XCV, 131-135.

PEIRIS, J. W. L. (1953a).
A Virus Disease of Cacao in Ceylon.
Trop. Agriculturist CIX, 135-138.

————(1953b).
Chilli leaf-curl complex.
Trop. Agriculturist CIX, 201-204.

————and DE ZILVA, J. (1954).
Fungicidal control of late blight of potato at Rahangala.
Trop. Agriculturist CX, 201-216.

————(1960).
An unrecorded virus disease of tobacco.
FAO Plant Prot. Bull IX, 109-110.

PERIES, O. S., FERNANDO, T. M. and SAMARAWEERA, S. K. (1959).
Control of white root disease (*Fomes lignosus*) of *Hevea brasiliensis. Q. Jl. Rubb. Res. Inst. Ceylon.* 41, 81-89.

SHANMUGANATHAN, N. and REDLICK, W. W. (1965).
Control of *Poria* root disease with methyl bromide. *Tea Quart.* 36, 144-150.

SECTION D—NATURAL SCIENCES

Presidential Address

TRAWLER FISHERIES OF CEYLON

by

A. S. MENDIS*

INTRODUCTION

Before the arrival of the Portuguese in Ceylon in the seventeenth century, the Island's fishing industry ranked second in economic importance only to her agriculture. The maritime areas which paid their annual taxes in pingo loads of dry fish provided the Sinhalese kings with considerable revenue (Deraniyagala, 1933). Successive foreign governments, the Portuguese and the Dutch, not only gradually increased these taxes but also controlled and taxed the salt at the production centres. These measures resulted in a decline of the fishing industry and a steep increase in the import of cured fish products particularly from South India.

During the early part of the nineteenth century, the fishing industry in Ceylon was at a very low ebb, and the volume of imported cured fish was increasing from year to year. The British Colonial Government took a serious view of this situation and in 1840 did away with the centuries old fish tax and imposed an import duty on fish products brought into the Island from abroad. These measures met with only a limited success. The revival of the fishing industry which had been on the decline for several centuries was very slow. The need for increased fish production became even more pressing with the passing years since the population was increasing in rapid proportions.

With the turn of this century more positive steps began to be taken to reorganise the fishing industry, in view of the ever-increasing demand for fresh fish. One of the steps was to look into the feasibility of starting a trawler fishery in Ceylon waters as this method was proving a success in U.K. at the time. With this end in view, a survey for suitable trawling grounds was undertaken, and a commercial fishery established in 1928. Since then trawling operations have continued to date with a break between 1936 and 1945 and provided ample evidence that this method of fishing could be further expanded on a profitable basis.

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The Ten Year Plan of the National Planning Council (1959) in its section on Fisheries Development, hoped to make Ceylon self-sufficient in fish requirements by 1968, provided for the operation of 17 trawlers from Ceylon by that year. The Ceylon Fisheries Corporation in 1965 issued a Draft Ten-Year Plan for the development of the fishing industry. This plan envisaged that by 1976 the Corporation would operate 20 trawlers providing Ceylon with 16,000 tons of fish annually.

The trawler fishing industry is now firmly established in Ceylon. This address will deal with the history and trends of this industry and attempt to evaluate the fish production potential from this source. Discussion will be limited to medium-sized trawlers of the 200-300 ton class, hitherto operated from Ceylon. Only passing references will be made to small inshore trawlers of the 11-ton or slightly heavier class and to large trawlers with freezing facilities which could operate in distant trawling grounds such as those in the Arabian Sea.

TRAWLING GEAR AND TRAWLERS

There is a misconception in many people's minds that any large fishing vessel is a trawler. This is not so. A trawler, be it big or small, is specifically constructed and equipped to operate trawl fishing gear and hence its name.

Trawling is a specialized method of fishing, involving the use of a large cone-shaped net termed the trawl net which is towed by means of a trawler. Any fish in the way of the net are forced into it through its mouth. The net gradually tapers backwards into a bag-shaped repository for the fish, termed the cod end. Trawl nets are either towed along the bottom of the sea, in which case the net is designated a bottom trawl net, or towed at any desired level between the surface and sea bed, when the net is termed a mid-water trawl net. The mouth of the net is kept open either by a rigid beam across the top of the mouth of the net, or by the pressure of the water upon two wooden kites or vanes referred to as otter boards which are attached to each side of the net's mouth. The former type is called the beam trawl net and was first operated from sailing vessels before the advent of the motorised fishing boats. Smaller fishing craft in inshore waters still operate beam trawl nets. The otter trawl is almost universally employed by deep sea trawlers today, and is by far the most efficient method yet devised for capturing fish that live at or very near the bottom of the sea.

HISTORY OF TRAWLER FISHING IN CEYLON

Trawler fishing operations in Ceylon can be described under two categories, firstly, those of an exploratory type or in the nature of surveys and secondly, those conducted as commercial fishing operations.

(1) Survey Operations

Before the Government of Ceylon took step to survey the seas around Ceylon to locate suitable trawling grounds, a Colombo businessman in 1902 fitted a steamer for trawl net fishing and tried it off Colombo. He must have been prompted to take this step in view of the success of trawlers in Britain at the time and possibly as a result of discussions he may have had with Prof. Herdman and other British biologists closely associated with fishery problems who were in the Island that year. He must have had some success because that same year he brought down the trawler "Violet" and operated it off Colombo but was only able to operate for a very brief period. The trawling operations failed because of clashes with fishermen fishing by traditional local techniques. Fearing set-backs to their means of livelihood, these fishermen organized a boycott of fish landed from the trawler. That was the end of the trawling attempt in 1902, and this attempt could be classed as more or less of an exploratory or survey nature.

The Ceylon Company of Pearl Fishers bought the trawler "Violet" and, in 1907, after obtaining the services of Capt. Cribb, a trawling master of Grimsby, U.K., utilized the trawler to look into the possibility of trawling in Ceylon waters. The "Violet" made two exploratory trawling cruises in 1907 which indicated the presence of two trawler fishing areas, namely, the Wadge and Pedro Banks (Hornell, 1916).

As a result of constant agitation by the Marine Biologist to take active steps in regard to the food fisheries of Ceylon, in 1919, the Government sanctioned a comprehensive Marine Biological Survey of the littoral waters of the Island. One of the aims of this work was to discover and survey any fishing grounds that were suitable for trawling. For this purpose the trawler "Lilla" was fitted out and the survey was carried out between the years 1920 and 1923. This preliminary but comprehensive survey of the entire coastal waters of Ceylon and also of the shallow-water area of the Wadge Bank off Cape Comorin in South India revealed that there were only two possible areas for conducting commercial trawler fishing operations from Ceylon. They were the Pedro and Wadge Banks (Fig. 1) the two areas referred to by Hornell.

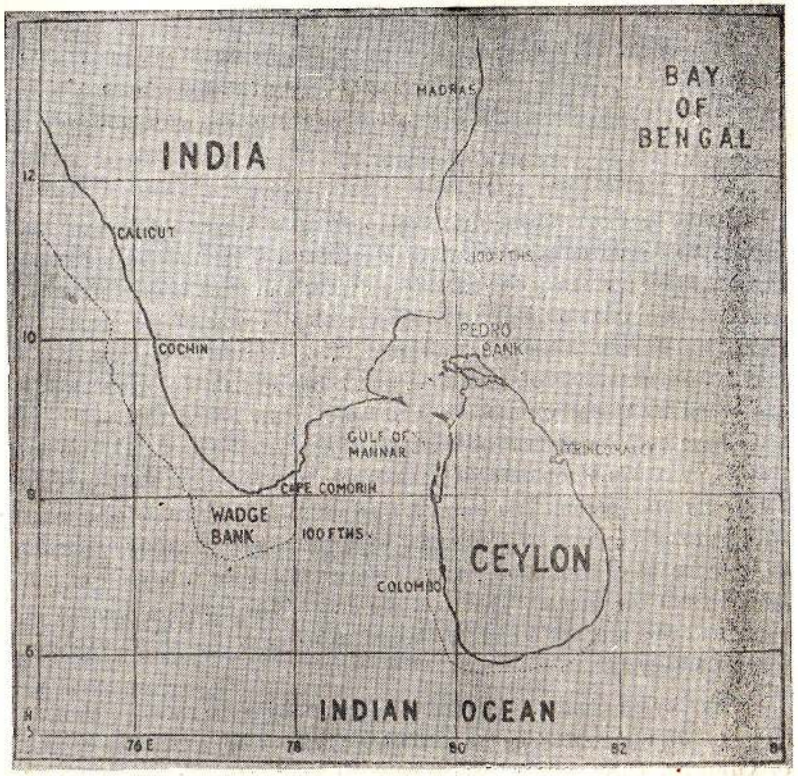


Fig. 1. Map of Ceylon and South India showing the relative positions of the Wadge and Pedro Banks. (Reproduced from Sivalingam and Medcof 1957).

The Pedro Bank is an extensive shallow water plateau situated off the extreme north-east corner of the Island stretching across the Palk Strait and extending some distance up the Indian coast. The Bank covers an area of about 1,000 square miles. During the survey, the catches obtained were only 126.3 lbs. of fish per hour trawling.

The Wadge Bank lies outside the Indian territorial waters off Cape Comorin. It has an area of over 4,000 square miles and was found to be the most suitable ground for trawler fishing from Ceylon. During the survey, 195.3 lbs. of fish were captured for each hour of actual trawling.

Immediately following the survey of 1920-23, the fisheries steamer "Nautilus" was sent to Wadge and Pedro Banks to ascertain in more detail the prospects of commercial trawling operations on the two Banks.

Pearson (1926) in his report to the Government on the prospects of trawling in Ceylon, indicated that the establishment of a trawling industry in Ceylon would be a financial success and estimated that a trawler operating in both the Wadge and Pedro Banks could bring in between $362\frac{1}{2}$ and $387\frac{1}{2}$ tons of fish a year. He arrived at these figures assuming that the trawler would fish in the Wadge Bank during the North-East Monsoon and in the Pedro Bank during the South-West Monsoon. He further pointed out that the fishing in the two banks would be profitable if the Wadge Bank produced $1\frac{3}{4}$ tons of fish per day and the Pedro Bank $1\frac{1}{2}$ tons per day.

(2) Commercial Trawler Operations

The Government surveys having convincingly proved that the prospects for commercial trawling from Ceylon was feasible, a private Company—"Ceylon Fisheries Ltd." was formed and in 1928 the Company brought down two coal-burning steam trawlers—the "Tong Kol" and "Bul Bul". These two trawlers fished both in the Wadge and Pedro Banks. Their attempts at trawling lasted till 1935 in which year the Company went into liquidation. The failure of the company was mainly due to the inability to find a market for the fish landed by their trawlers.

To augment Ceylon's food supplies, the British Ministry of War Transport placed at the disposal of the Ceylon Government a reconverted trawler "Raglan Castle" which arrived in Ceylon in 1945. This was a trawler built in 1919, and with constant repairs she was able to carry out trawling operations till 1951. During 1947-48 a private Company operated the coal-burning steam trawler "Aringa". Records of her operations are not available.

In 1951, the Department of Fisheries started operating the oil-fired steam trawler the "Braconglen" and in 1953, a similar trawler the "Maple Leaf" gifted by Canada under the Colombo Plan commenced commercial operations. Unlike the earlier trawler fishing ventures by the private compaines, the Department of Fisheries was able to organize better marketing facilities for the fish landed by its trawlers. A further improvement in the disposal of the fish was made possible with the opening of the fish factory at Mutwal. Here the fish could be frozen and stored for long periods and released as required. Shortly after the publication of the Ten-Year Plan of the National Planning Council in 1959, an order was placed for 5 new diesel engine-driven stern trawlers. The first of these went into operation in 1964. The other four arrived during 1966, and all five are now being operated by the Ceylon Fisheries Corporation. The Corporation today operates a fleet of six trawlers—five stern trawlers and the side trawler "Maple Leaf".

The private sector has also been engaged in trawler fishing activities in recent years. After the Mutwal Fish Factory was inaugurated, a private Company constructed a bigger factory in Colombo, and this Company chartered a few trawlers from Japan and operated them on the Wadge Bank between 1961 and 1963.

TABLE I

Name of Trawler	*Period of Operation*	*Type of Trawler*	*Gross Tonnage*	*Refrigeration*	
				Capacity Tons	*Temp. °F*
Violet	1902 & 1907	Coal Fired Steam Trawler	150	None	—
Lilla	1920-1923	—do—	250	,,	
Tong Kol	1928-1929	—do—	292	70	24-38
Bul Bul	1928-1935	—do—	294	65	14-20
Raglan Castle	1945-1951	—do—	280	50	28
Aringa	1947-1948	—do—	305	100	20-24
Braconglen	1950-1963	Oil fired Steam Trawler	392	105	30-31
Maple Leaf	1953 to date	—do—	323	119	30-31
Daiski Maru	1961	Information not available			
Kyoski Maru 6, —do— 12, —do— 13	1962-1963	Three Bull Trawlers that operated together			
Gandara	1964 to date	Diesel Engine Driven Stern Trawler	238	97	33
Boston Spitfire	1965 to date	Diesel Engine Driven Side Trawler	166	66	32
Lowestoft Lady	1966	—do—	166	66	32
Beruwela, Pesalai, Myliddy, Meegamuwa	1966	Diesel Engine Driven Stern Trawlers	238	97	33

More recently two new companies have been formed and they are now operating a trawler each on the Wadge Bank.

All the trawlers that have been operating from Ceylon so far have been using bottom trawl nets and capturing only the demersal varieties of fish.

Table I gives a summary of all the trawlers that have been operating from Ceylon so far.

TRENDS IN CEYLON TRAWLERS FISHERIES

(1) Areas fished by Trawlers operating from Ceylon

At present the only Port in Ceylon with facilities for handling trawlers is Colombo. A trawler exploiting the Pedro Bank from Colombo will take about 40 hours to reach the fishing grounds. With about 4 days lost in a steaming to and from the fishing grounds, it would not be economical to fish the Pedro Bank. This situation would change if facilities for handling trawlers are made available at Trincomalee. Only occasional trial fishing trips have been made to the Pedro Bank in recent years although between 1928 and 1935 it had been fished more frequently. The Wadge Bank is about 18 hours steaming from Colombo and at present all Ceylon-based trawlers exploit this Bank only.

No records are available of the exact area of operation of the "Tong Kol" and "Bul Bul" on the Wadge Bank. The "Raglan Castle" only fished the South-Eastern portion of the Bank which approximates 65 square miles in extent, and is the portion of the Bank lying closest to Colombo. An analysis has been made of the frequency of trawler operations between 1956 and 1964 on the Wadge Bank (Mendis, 1965a). This analysis shows that the Bank has not been evenly fished and that two areas have been fished much more frequently than the rest of the available trawling ground. These two areas of the Bank account for only about 650 square miles of the 4,000 square mile Wadge Bank (Fig. 2). No satisfactory explanation can be given for this unevenness in the exploitation of the Bank and with the expansion of fishing, trawlers will have to move out to more unfamiliar areas in the Bank.

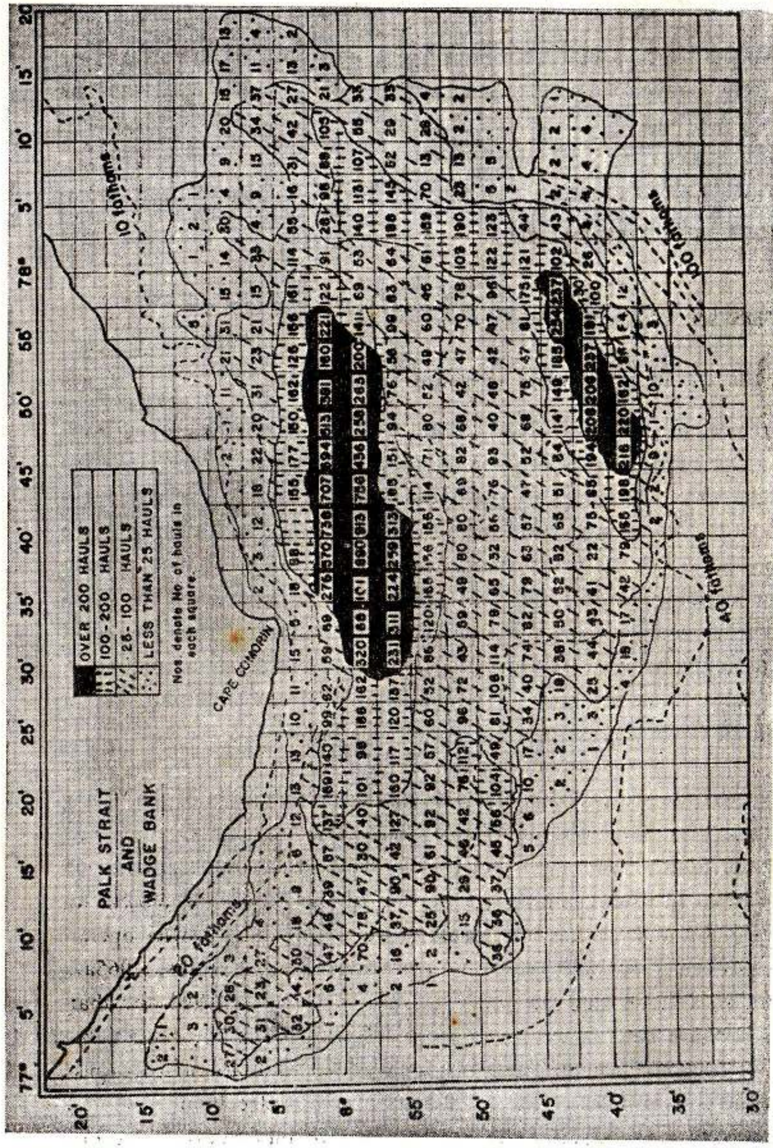


Fig. 2: Distribution of Fishing Effort on the Wadge Bank. (Reproduced from Mendis 1965a). The numbers denote the number of hauls in each square. Note the following errors, 68 in the square at N 7° 58′ E 77° 33′ should read 685; and 101 at N 7° 58′ E 77° 37′ should read 1011.

(2) Incentive Bonus Scheme for Crews of Trawlers

The mode of payment to officers and crews of Government-owned trawlers was fixed salaries plus overtime according to Government Financial Regulations. The maximum overtime payable on these regulations was limited, and such overtime was earned by the crew in a couple of weeks each month. Accordingly, there was a tendency for a trawler to stay in harbour after the crew had earned their maximum overtime for each month.

In order that the trawlers could spend more days fishing, there was a move as early as 1958 to introduce an incentive bonus scheme, which envisaged the payment of a portion of the value of the catch for each trip, in lieu of the overtime earned by the officers and crew. The officers accepted the scheme but not the crew. Finally in 1964, the entire crew accepted a modified scheme, and today the Fisheries Corporation continues to pay an incentive bonus to the crew. The bonus has to be earned by the crew and the amount of bonus paid out depends on the value of the catch landed. No overtime is paid. At the end of each year, a further bonus is paid out to trawlers that have made over 16 fishing trips and have brought in fish whose value is over one million rupees for the year.

With the introduction of this scheme as the bonus paid out depends on the value of the catch, there has been a tendency during the past two years or so for trawler crews to be more selective in the fish stored in their hatches and finally landed in Colombo. Since much time and energy is lost in treating inferior varieties of fish like skates and catfish, these varieties are often discarded with the hope of filling their holds with good quality fish which fetches a higher value. Although records of such discards have not been kept by the trawlers in the past, discussions with the trawler officers revealed that an average of about 25% of the fish captured are discarded. After Trip No. 12 of "Pesalai" which lasted from 10th to 24th September, 1966, she landed 72,720 lbs. of good quality fish. Her records showed that 40,120 lbs. of inedible or inferior varieties of fish had been thrown overboard. On this particular trip, the quantity discarded, therefore, amounted to 35% of the catch. There had always been discards in earlier years too, but not to the extent that has been done since the introduction of the bonus scheme. For purpose of analysis and discussion of the trends in Ceylon trawler fisheries, 20% has been added to the recorded fish catches for 1964 and 1965, and these enhanced values have been used in comparing the values with those of earlier years.

(3) Total Fish Landings by Trawlers

Pearson (1926) envisaged that two trawlers fishing the two Banks could bring in about 1,750,000 lbs. of fish in one year, i.e. 875,00 lbs. per trawler per year. When commercial fishing first commenced in 1928, the target was not reached and the trawlers "Tong Kol" and "Bul Bul" landed only about 600,000 lbs. of fish. From 1930 onwards upto 1935, when "Bul Bul" alone operated, she landed between 600,000 and 1,300,000 pounds of fish per year. The "Raglan Castle" was never able to exceed the target of 875,000 lbs. of fish per year. Her average was around 550,000 lbs. The "Braconglen" brought in an average of about 1,500,000 lbs. of fish a year until 1963, her last year of operation. The "Maple Leaf" has been more consistent in her fish landing figures and has averaged about 1,400,000 lbs. per year. There have been years when each of the trawlers "Braconglen" and "Maple Leaf" brought in more than 1,800,000 lbs. of fish. Indications are that in future, trawlers could each maintain or even exceed the 1.8 million pounds per year.

The total fish landings from trawlers give some indication of the production potentialities of trawlers. A clearer picture of the general trends can be obtained by analysing the landings (or catch) and operational data to determine the catch per unit effort for each trawler. Three criteria are available for such an analysis of catch per unit of effort. They are catch per trip, catch per day out of Port and catch per trawling hour.

(4) Catch per Trip

Pearson and Malpas in issuing their report in 1926 took it for granted that trawlers working from Ceylon would have a refrigerated fish hold capacity of 10 tons only. They estimated that 31 cwt. of fish could be captured from the Wadge Bank per day, and, therefore, calculated that the hold could be filled up in 7 days. They thereby implied that a trawler could bring in a maximum of 22,500 lbs. (10 tons) of fish per fishing trip.

The trawlers "Tong Kol" and "Bul Bul" had refrigerated holds with a capacity of over 60 tons each, and judging by their total landing figures, it could be assumed that they were bringing in well over 22,500 lbs. of fish per fishing trip.

The "Raglan Castle" had a capacity of 50 tons, but her fishing records reveal that her fishing trips were of short duration lasting at most seven days. Her average fish landings per trip amounted to 32,000 lbs.

The "Braconglen" and "Maple Leaf" both had fish hold capacities of over 100 tons. During its first year of operation "Braconglen" realized an average of 38,000 lbs. of fish per fishing trip, and this figure was progressively improved upon each successvie year. Over a twelve-year period, the two Government trawlers "Braconglen" and "Maple Leaf" have each averaged 80,000 lbs. of fish per trip.

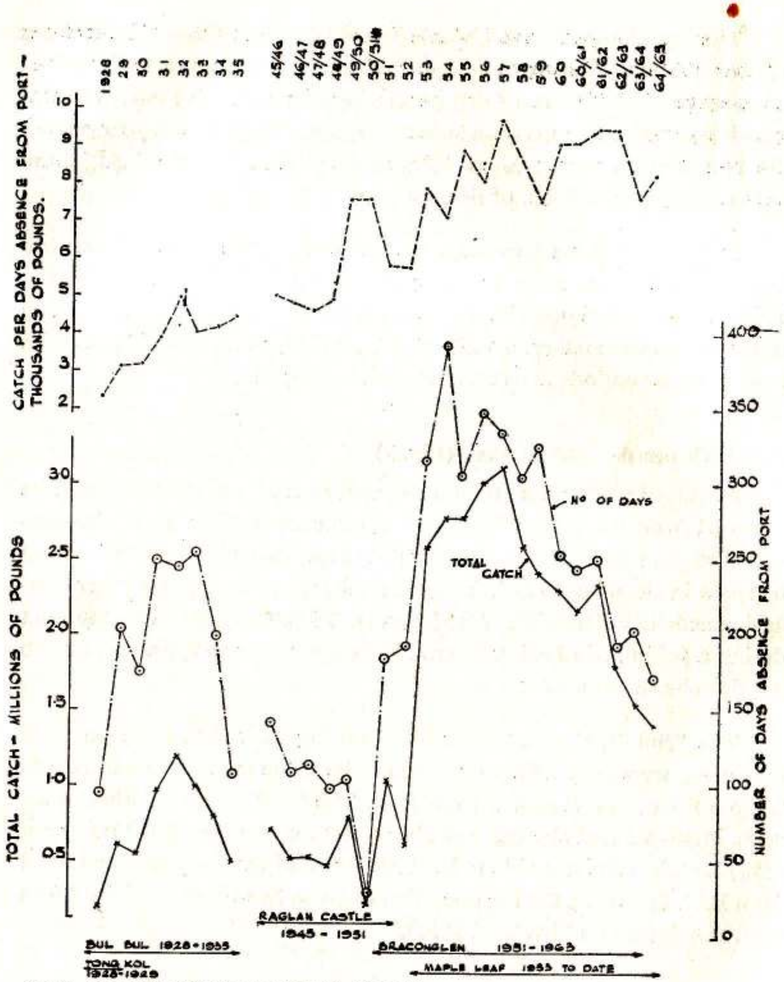
It is seen that trawlers have been able to realize more fish per trip in successive years since trawling operations commenced in Ceylon. This has been made possible by the operation of trawlers with increased refrigerated fish holding capacities and providing trawlers with facilities to stay longer periods at sea during each fishing trip.

(5) Catch per day out of Port (Fig. 3)

Pearson and Malpas (1926) estimated that 31 cwt. of fish could be captured from the Wadge Bank during each day fishing. They also estimated that a fishing trip would last nine days, of which two days would be spent in steaming to and from the fishing grounds and on other non-fishing activities. Therefore, 7×31 cwt. i.e. 24,300 lbs. would be captured during a fishing trip lasting 9 days. This works out to 2,700 lbs. of fish per day absent from Port.

The "Bul Bul" and "Tong Kol" during their first three years of operation, were only able to maintain the value given by Pearson and Malpas for each day absent from Port. The "Bul Bul's" efforts in later years improved and she was realizing 4,000 lbs. per day, 1932 being her best year when she was able to land 5,000 lbs. of fish for each day absent from Port. (The data for the operation of these two boats has been taken from Sivalingam and Medcof, 1957).

When trawling operations recommenced on the Wadge Bank in 1945, the quantity of fish captured for each day absent from Port was 5,500 lbs. This kept on increasing year by year, and the "Raglan Castle" during her period of operation averaged 6,200 lbs. per day out of Port. In recent years, the value has steadied itself to around 9,000 lbs. To a certain extent, this increase can be explained by the fact that trawlers remain for longer periods out at sea than before. The increase is over 300% of Malpas' estimate which was 2,700 lbs. The increase in recent years would have been higher but for the large scale discards of inferior varieties.



* DATA FOR PERIOD OCTOBER TO DECEMBER 1950 ONLY.

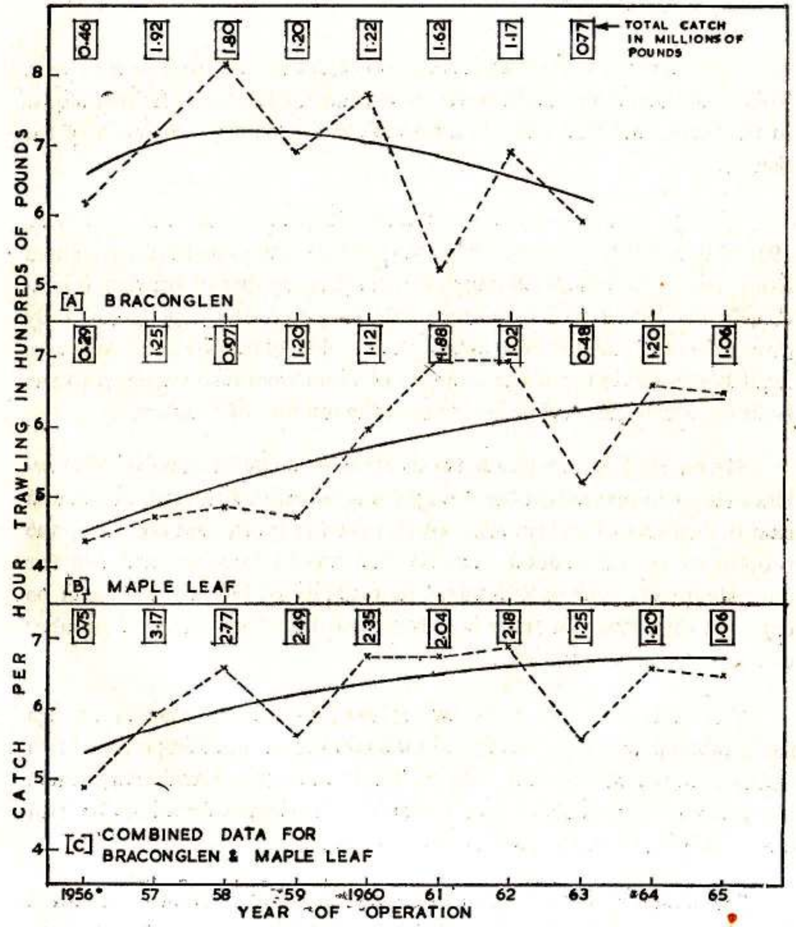
FIG.3 TOTAL CATCH, Nº OF DAYS OUT OF PORT AND CATCH PER DAY OUT OF PORT

(6) Catch per Hour Trawling (Fig. 4)

Pearson and Malpas (1926) envisaged that a commercial trawler operating in the Wadge Bank would be able to haul in 300 lbs. of fish for each hour trawling. The actual trawling times of the "Tong Kol" and "Bul Bul" are not available. "Raglan Castle" between 1945 and 1947 averaged about 420 lbs. per trawling hour. In 1950, this value had risen to 500 lbs. Comprehensive and detailed records are available for the

operation of the two trawlers "Braconglen" and "Maple Leaf" after October, 1956. These records show that the trawlers have been fishing steadily and averaging over 575 lbs. per hour trawling.

The quantity of fish captured by "Braconglen" increased from 613 lbs. per trawling hour in 1956 to 711 lbs. in 1957, and 815 lbs. in 1958, the highest value so far recorded by any trawler. Since that year there has been a steady decline in her average catch to 582 lbs. per trawling hour in 1963—her last year of fishing. This decline in the catch can mainly be attributed to the gradual deterioration of the condition of the trawler.



* 1956 VALUES ONLY FOR THE 3 MONTHS PERIOD— OCT, NOV & DEC

FIG. 4 CATCH PER HOUR TRAWLING

The "Maple Leaf's" record of catch per trawling hour has steadily increased from year to year. She started off with 435 lbs. per trawling hour in 1953 and in 1965 the value was 646.

An analysis of the combined data for the "Braconglen" and "Maple Leaf" also indicates that the trend is for an increase in the quantity of fish captured for each hour of trawling over the years.

FISH PRODUCTION BY DEMERSAL TRAWLING ON THE WADGE BANK

The catch per unit effort has been on the increase from year to year. This is an indication that increased effort has not depleted the fish stocks in the bank, and that there is a possibility for further expansion of the fishery.

Foreign fishery experts (Hickling, Blegvad, John and Kestevan, 1951; Medcof, 1963; Tiews, 1963) who were consulted by the Government from time to time have all suggested that the number of trawlers operating from Ceylon could be increased. However, the experts not only differed on the number of trawlers that could operate on the two banks available to Ceylon, but the majority of them were also vague as to the basis on which they had recommended the number of trawlers.

Recent studies have made it possible to evaluate the number of trawlers that could operate on the Wadge Bank by estimating first, the annual rate of increase of the quantity of fish on the bank, and secondly, the proportion of the annual increase that would become available for harvesting each year by trawlers. The quantity of fish a trawler can be expected to harvest annually is known, and therefore, the total number of trawlers can be evaluated.

The value of 575 lbs. per trawling hour, considered to be an average for trawlers since 1956, was used in calculating the standing crop of fish in the Wadge Bank (Mendis, 1965b). The standing crop, which amounted to 18.5 million pounds of fish, comprises the demersal varieties of fish captured by the bottom trawl net from the bank.

The standing crop of fish in the bank is being constantly increased by the addition of new recruits and the growth of the existing fish. Simultaneously, there is a decrease in the quantity as a result of mortality due to fishing and natural causes. If the total increase in weight over a given period is equal to the total mortality, the value for the standing crop would remain constant. For purposes of discussing and working out the potential fish productivity for the Wadge Bank, the fishing will be restricted to limits so that the total replenishment of fish is equal to the total mortality each year. Thus the standing crop will remain constant.

Prasad and Nair (1960; 1963) in their studies on primary productivity in the shallow coastal waters in the Gulf of Mannar indicated the potential fish production for this area. Prasad (1966) stated that more recent studies in the area have confirmed their 1963 findings. He further stated that they had extended their studies to the West coast of India and found that the shallow area of the Wadge Bank was by far the most productive (in terms of primary productivity) of all the Indian coastal waters they had studied so far.

Based on Prasad and Nair's primary productivity studies, the fish productivity of the shallow waters of the Gulf of Mannar has been estimated to be in the region of 75 to 110 tons per square mile, the values decreasing with the depth of the water and the distance from the shore. Since the Wadge Bank goes up to a depth of 100 fathoms and extends a considerable distance from the shore, its fish productivity is taken to be an average value equivalent to half the maximum productivity, i.e. 110/2 tons per square mile per year. On this basis, the total productivity of the 4000 square mile Wadge Bank would be $4000 \times \frac{110}{2} \times 2240 =$ 490,000,000 lbs. of fish per year. It would now be necessary to estimate what proportion of this production can be harvested by trawlers.

Steele (1965) also working on primary productivity, was able to indicate that only 22% of the total quantity of fish produced in the North Sea comprise the demersal varieties of fish. On this basis the quantity of demersal fish produced annually on the Wadge Bank would amount to 22% of 490,000,000 lbs. = 108,000,000 lbs.

Steele has also shown that in the North Sea the annual mortality of fish due to fishing activities is 75% of the total mortality, the balance 25% being mortality due to natural causes. To make the estimate very conservative, 50% of the annual production can be allowed for natural mortality, and only the balance 50% i.e. 54,000,000 lbs. would be considered available for harvesting by trawlers each year. As the fishing effort increases over the years, the percentage of fish removed from the Bank by trawlers can be increased and a smaller percentage be allowed for natural mortality. As it has been earlier indicated that trawlers discard 35% of their catch (inedible and inferior varieties), the balance 65% of 54,000,000 lbs. i.e. 35,000,000 lbs. of good quality fish could be brought in by the trawlers. It was also shown that a trawler could bring in 1.8 million pounds of fish a year. Therefore, about 20 trawlers can be operated on the Wadge Bank to exploit the 35,000,000 lbs. of good quality fish.

FISH PRODUCTION FROM OTHER SOURCES

Besides the Wadge Bank stocks of demersal fishes which are being exploited at present, the following additional sources are available for harvesting by Trawlers:—

(1) The demersal fish in the Pedro Bank;
(2) The pelagic fish in the Wadge and Pedro Banks;
(3) Demersal fish stocks in the coastal areas;
(4) Demersal and pelagic fish stocks in distant trawling grounds.

(1) The Pedro Bank

It was estimated that the standing crop of fish in the Bank is 3,000,000 lbs. (Mendis, 1965), which value is one-sixth the value for the Wadge Bank. On this basis the stock of fish in the Pedro Bank that would be available for harvesting each year would be 1/6th of 35,000,000 lbs. (the quantity for the Wadge Bank) i.e. approx. 6,000,000 lbs. This quantity could be harvested by four or five trawlers. At present the Bank is not being utilized at all.

(2) Pelagic Fish

Pelagic varieties constitute 78% of the total quantity of fish produced (as stated earlier). Trials with a mid water trawl net have just commenced. These trials will show the feasibility of operating mid water trawls on both the Wadge and Pedro Banks. The quantities that could be harvested will also be indicated by these trials.

(3) Coastal Trawling

Recently the Ceylon Fisheries Corporation introduced a fleet of 11-ton boats for trawling operations in the shallow coastal water areas. Earlier trials had indicated the possibility that these trawlers would be able to harvest considerable quantities of prawns. The coastal waters invariably have large quantities of low quality fish for which a market will have to be established. Much preliminary surveys and experimental work have to be carried out before any assessment can be made of the resources available for exploitation by these small trawlers.

(4) Distant Water Trawling

Recent studies made during the International Indian Ocean Expedition have revealed that there are several areas in the Indian Ocean which are exceptionally rich in nutrient content. These areas are accordingly very productive and contain large stocks of fish. One such area is in the Arabian Sea off the Coast of Oman. Russian trawlers operating in this area have obtained good catches of fish. Ceylon based trawlers with freezing facilities could quite conveniently operate in this area. A group of Ceylonese businessmen have already on order such a trawler, and it will probably be in operation early next year.

DISCUSSION

This address on the trawler fisheries of Ceylon clearly illustrates the fact that in the past insufficient attention had been paid to the utilization of Ceylon's food resources. The main concern had been the development of industries that provided considerable revenue or those that formed export commodities.

Although the prospects of trawling in Ceylon had been shown to be good, the early attempts failed due to the problem of the disposal of catches. There are other problems that need be tackled before a full exploitation of the resource can be accomplished. This will involve the efforts of not only biologists, but also those of several other scientists like gear and food technologists, refrigeration and marine engineers, to mention only a few. The entire problem of utilization of the resource has to be viewed as a whole and not one of merely introducing more fishing vessels.

Expansion schemes of recent years have attempted to co-ordinate these various aspects and are providing a sounder basis not only for expanding the trawler fishery but also the development of other forms of fishing. It is hoped that this scientific approach to the fishing problems will not only make Ceylon self-sufficient in fish, but will eventually earn foreign exchange and be one of the major sources of revenue as in the days of the Sinhalese Kings.

References

DERANIYAGALA, P. E. P. (1933). Cured Marine Products of Ceylon. *Ceylon J. Sci.* (*C*) **5**, 49-79.

Development Plan (1965). *Draft 10-Year Plan for the Development of the Fishing Industry*. Ceylon Fisheries Corporation, Colombo Ceylon.

HICKLING, C. F., BLEGVAD, H., C. C., and KESTEVAN, G. L. (1951). *Ceylon Fisheries. Recommendations of Experts on Fisheries Development, Research, Socio-Economic and Industrial Problems*. Sessional Paper No. 6 of 1951. Government Press, Ceylon.

HORNELL, J. (1916). Madras Fisheries Department Bull. No. 8 Cited by Malpas (1926). *Ceylon J. Sci.* (*C*) **2**, 13-165.

MALPAS, A. H. (1926). The Marine Biological Survey of the Littoral Waters of Ceylon. *Ceylon J. Sci.* (*C*) **2**, 13-165.

MEDCOF, J. C. (1936). Partial Survey and Critique of Ceylon's Marine Fisheries. *Bull. Fish. Res. Stn Ceylon* **16**, 29-118.

MENDIS, A. S. (1965a). The Trawler Fishery. *Bull. Fish Res. Stn Ceylon* 17(2): 268-274.

Ibid., (1965b). Resources of the Wadge and Pedro Banks. *ibid.* **18**: in press.

PEARSON, J. (1926). *Prospects of Trawling in Ceylon*. Sessional Paper No. 14 of 1926, Government Press, Ceylon.

PEARSON J. and MALPAS A. H. (1926). A Preliminary Report on the possibilities of commercial trawling in the sea around Ceylon. *Ceylon J. Sci.* (*C*) **2**, 1-12.

PRASAD, R. R. (1966). *Productivity Measurements in the Indian Ocean*. Lecture delivered at a UNESCO sponsored Oceanography course in February, 1966. (Unpublished).

PRASAD, R. R. and NAIR P. V. R. (1960). A preliminary account of primary production and its relation to fisheries of the inshore waters of the Gulf of Mannar. *Indian J. Fish.*, **7**, 165-168.

Ibid., (1963). Studies on Organic Production I. Gulf of Mannar—*J. Mar. Biol. Ass. India.* **5**, 1-17.

Report by the National Planning Council. (1959). *The Ten-Year Plan*. The Planning Secretariat, Colombo, Ceylon.

SIVALINGAM, S. and MEDCOF, J. C. (1957). General Features and Productivity of the Wadge Bank Trawl Fishery. *Bull. Fish. Res. Stn Ceylon* **6**, 1-23.

STEELE, J. H. (1965). Some Problems in the study of Marine Resources. *ICNAF spec. Publ.* **6**, 463-476.

TIEWS, K. (1963). *Report on the Fishery of Ceylon and the Possibilities of Development under special consideration of the Construction of Fishing Ports in Galle and Trincomalee*. Sessional Report No. 20 of 1963. Govt. Press, Ceylon.

SECTION E—PHYSICAL SCIENCES

Presidential Address

THE FUTURE OF INDUSTRY IN CEYLON

by

G. PONNAMPERUMA

1.1. Developing countries are now convinced that industrialisation is essential for general economic and social progress. In Ceylon, various short-term or medium-term plans and schemes for industrial development have been put out from time to time over several decades. These have not been very effective, one reason being the absence or inadequacy of overall development planning. The position is now different with the recent elevation of economic planning to that of a ministerial subject under the Prime Minister himself. However, the base of science and technology in the country is quite inadequate for techno-economic planning or for bringing to fruition, plans already conceived on bread economic considerations. Hence, the organisation of Science and Technology complementary to economic planning is a matter of utmost priority. Now that steps in the right direction have been taken in the sphere of economic planning, it remains to do likewise in that of Applied Science as a complementary counterpart.

1.2. The same features as characterised the past continue in the present pattern of industrialisation, namely:—

1. Pre-occupation with import substitution of a multiplicity of consumer goods. This has tended to detract attention from the far reaching objectives of real industrial advancement, namely the development of new or improved products based on our natural resources, which are principally agricultural and to a lesser extent, mineral.
2. Even in the development of certain key industries such as fuel, chemicals and structural materials, the dominant import substitution outlook has precluded techno-economic planning of

these industries as the basis of future industrial growth. In programmes and policies of public utility development such as power and transport, the outlook is likewise one of meeting primary needs rather than of adapting them to the needs of industrial expansion.

3. The development of the requisite scientific and managerial services continue to be neglected. Certain categories of critical skills such as Research Scientists and Technocrats, are almost non-existent. As a result there is an over-dependence on foreign skills and advisory services which are often intermingled with the commercial interests of purveyors of supplies and services. The need for changing the educational system, which for years has been out of step with the economic needs of the country, is only just being felt. Over the last two decades or so, there has been an actual shrinkage in the output of technologists, when they should have increased ten-fold. Simultaneously there has been a serious brain drain from the country on account of its uncongenial environment for technical personnel.

4. Organisational and institutional arrangements are totally inadequate to meet the requirements of technical and managerial services. The pace of achievement is slowed down by obsolete administrative attitudes and procedures. From a scientist's point of view it is not surprising that as has been reported, Ceylon is one of the few countries in Asia, in which the per capita income has declined over the last few years.

2. IMPORT SUBSTITUTION

2.1. The pattern of industrialisation that is being followed in both public and private sectors, subject to minor exceptions, is one of import substitution and is based on the imitation of manufacturing techniques and products known elsewhere. Such an approach may be unavoidable at the initial stages of industrialisation. However, its benefits could be temporary or questionable in many instances, unless it be made to serve as the starting point for real technological advancement into more creative spheres.

2.2. In the private sector particularly, the recent increase in the volume of industrial output is by and large from a multiplicity of small consumer goods extensively dependent on imported processing materials. These, as could be expected under current conditions, are generally of a category, where a quick turnover is possible and have come into existence under the stimulus of protective measures. In contrast, most of the industries reserved for the public sector are more substantially based on local raw material processing and involving lesser foreign components of manufacturing cost, although such industries by their nature are more heavily capitalised and are dependent on extensions of public utilities such as ports, railways, and power and water supplies.

2.3. Pre-occupation with import substitution of a multiplicity of minor consumer goods has diverted attention from the real task of lasting industrial advancement, namely that of new products or improved products based on indigenous resources. The primary resources of this country are predominantly agricultural, hence real industrialisation lies in taking over primary agricultural products to a secondary stage of manufacture.

2.4. Imitative technologies may pass into obsolescence even before skills in their operation are mastered. Under such circumstances the benefits of local manufacture may be off set by increasing dependence on foreign services and supplies, and the substitution of goods of lesser quality, at a higher price to the consumer.

2.5. Improvements in quality, variety and price of both capital and consumer requisites, and the invention of new products are taking place today in the world at large at an unprecedented pace. Under-developed or so-called developing countries have lagged behind in this respect. Creative scientific and technological research have yet to make an impact even on the major commodities which sustain them. The gap between developed and under-developed countries, in scientific advancement is widening.

2.6. That the level of scientific and technological advancement is also the source of economic well being in a country is a well known fact. Low priority for scientific research and services is a characteristic of lesser developed countries. Hence, it is obvious that development cannot be accelerated unless this order of things is reversed. One reason for this low priority is an erroneous assumption which still persists that whatever technological knowledge is required could be obtained at will from the more developed countries and that scientific research is a luxury which a poor country cannot afford. This assumption also arises from a confusion of Science with Technology. Whilst Science is an advancement of knowledge, which is freely disseminated, Technology is concerned with the application of Science to definite economic objectives. It comprises "know-how" rather than pure knowledge. The developments of technology are somebody's property and have to be paid for. In the first place, the mere fact that a particular process or a particular manufacturing technique operates successfully in one place is no guarantee that it will do likewise in another. In the second place, the most vital sphere of technological know-how regarding the development of the internal resources of one country may not be readily available from another. Even a highly advanced country directs its technological research towards its own economic needs. If the results of such work have useful application elsewhere, it is only coincidental. Thirdly, it is not appreciated that the successful adaptation of processes and techniques known elsewhere to local conditions involves research and experimentation often of a fundamental nature and a sound understanding of their basic technologies.

2.7. The Ceylon tea, rubber and coconuts have already reached a stage of advancement as primary agricultural products, but their manufacturing technologies are still at a rudimentary level. Even the smallest innovation in the processing of technologies of these commodities will have far reaching economic implications, on account of their volume and value.

2.8. In agricultural commodities, the first phase of development has necessarily to be in the plantation sphere. At this stage, some technological advancement takes place, ancillary to cultivation and principally in the mechanisation of traditional manual operations. This pattern is to be clearly seen in the plantation industries of Ceylon.

2.9. When agricultural advancement has reached a level of maturity, the stage is set for a new phase of development in the processing technology of these primary products. Improvements in a modern industrial context to processes and products, utilisation of wastes, development of new processes and new products, design of new equipment are vital for the sustenance of commodities which may have enjoyed years of prosperity in the past.

3. TEA INDUSTRY

3.1. We do not have to look outside Ceylon for convincing proof. Although the cultivation and manufacture of tea had for centuries been in China, it is in Ceylon and in India that a new product superseded

within a few decades, the traditional commodity. This would never have been achieved were it not for the research and development work in new plantation techniques and manufacture. The early entrepreneurs of this industry gave high priority to scientific research and this has paid dividends. Tea faces a new challenge today. The complacency of an unchallenged export market over many years for Ceylon tea may have diminished, since, the incentive to keep pace with the advancement of Science. The position is now different, as Tea is running into a difficult period. If tea is to survive, extensive technological research is necessary in its processing methods, which however ingenious they may have been thirty to forty years ago, have remained more or less static since.

3.2. In terms of economic priorities for technological research, tea ranks first, followed by rubber and coconut. Even the smallest innovation in the processing of these commodities will have far reaching economic implications on account of their volume and value. This is in contrast to the return that could be expected from a similar effort in any of the smaller manufacturing industries.

3.3. RUBBER INDUSTRY

The success already achieved by a number of local industrialists in the manufacture of rubber goods based on latex, even in the face of inadequate technical and research services, is an indication that this industry could be stimulated to a sizable level, with an export market. Local rubber manufacturers have developed and put out new products. As such they are a significant exception to the general rule of import substitution. On account of its special local advantages, the manufacture of latex goods, is a promising line of new industry in a rubber producing country. On account of its versatile nature, rubber latex is a raw material, from which, with research and ingenuity, more and more new products can be invented.

3.4. COCONUT INDUSTRY

The progress that has been achieved up to now in the manufacture of products based on coconut, is by and large, the mechanisation of primitive manual operations. Fundamental progress in its process technology has been insignificant. The physics and chemistry of the coconut kernel, shell and fibre still await elucidation, likewise basic research on unit operations, such as drying, evaporation, centrifuging—as applicable to coconut—have still to be systematically studied. The process technology of coconut products is by modern scientific standards at a very rudimentary level. A unit operation basic to both tea and coconut is drying. Despite its importance, little or no fundamental scientific work has been done in this subject. As fundamental scientific data necessary for the efficient design of new processing equipment is lacking, operations must continue with equipment designed in an empirical manner, and with their accompanying limitations. It is hardly conceivable that in Ceylon as well as in certain other developing countries, the primitive wasteful methods of coconut processing should continue indefinitely. If modern science and technology are not applied to re-vitalise this industry, Ceylon may soon be outstripped by other countries who are now thinking on new progressive lines.

4. NEED FOR APPLIED RESEARCH IN LOCAL CONTEXT

4.1. The most fruitful field of technological research is the development of new products or improved products by new processes. As research is a venture into the unknown, it is not possible for planners to know in advance what new products precisely are likely to be forthcoming. However, experience has established one fact, that investment on research pays the highest dividends in an economic and social sense, in the long run. As a percentage of Gross National Product, the expenditure on research, by developing countries falls far below those of the developed countries. Ironically this is the reverse of what should be, as the need for development research in a developing country is greater than in one which has reached a satisfactory level.

4.2. Besides tea, rubber and coconut, there is a vast range of lesser known and unconventional natural products from which could be developed new processed commodities for local consumption, as well as for export. A sharp demarcation of industry and agriculture as different spheres of activity, is no longer conceivable. The development of one is so closely interwoven with the other. In fact, the next phase of development is the industrialisation of agriculture.

4.3. In order to effect this transition in a predominantly primary agricultural economy, development of certain key industries—these include chemicals, building and structural materials, along with the development of essential utilities such as power, transport and water

supplies—are necessary. In the public sector today, cement and steel industries are being developed or expanded. Likewise there are plans for a Petroleum Refinery and Nitrogen Fertiliser project. It is a great pity that these two last named projects have not been conceived of in terms of a petro-chemical complex with its immense future possibilities.

5. PERSONNEL

5.1. The development of the required scientific and research services is extremely time-consuming as its main limitation is personnel. Hence, it is a matter of extreme urgency that there should be a radical change in the present institutional and organisational arrangements which have retarded the emergence of such critical skills. In the first place, it is necessary to arrest the leakage out of the country even of the few specialist personnel who might have been available if conditions had been more congenial. The mere adjustment in emoluments of scientific, technical and managerial personnel will not suffice. A more important consideration is the generation of leadership, which has been so significantly absent in the scientific professions. One method would be to look for a first line of leadership from among younger scientists, and rapidly bring to the top those who display outstanding ability and bring up behind them a second line of younger persons, coming out of the Universities.

5.2. While the needs of the country in applied research have never been so acute as before, it is extremely disappointing to observe that even long established research institutes which have played an important role in the economic advancement of this country are now having a struggle for survival. There are also various scientific departments languishing today as appendages to larger administrative units, without the stimulus to progress and make a useful contribution to the country.

5.3. Last year, at the Opening Session of the C.A.A.S., the Hon. the Prime Minister, announced his intention to set up a Ministry of Science and Technology. The elevation of National Science to ministerial level, as in the case of economic planning, is a most urgent step, to ensure that science and science planning will be given its due place. It will also facilitate the organisation of research institutions, scientific departments and of scientific personnel to the economic and social needs of the country. It is also essential that there be a Research Council on the same lines as in U.K. or Canada, and composed of men of Science who have distinguished themselves in various spheres of Applied Scientific Research.

6. CONCLUSION

The attempts at industrialisation have not yet made an effective impact on the economic life of the country. The raising of national economic planning to ministerial level has within a short time brought about a new and hopeful outlook. In order that the objectives of economic planning be attained, it is essential that the scientific and technological services in the country be likewise organised as an instrument of national planning. The past and present industrial pattern of import substitution is inadequate unless it be considered as a transitional stage to one of secondary production based on indigenous resources of this country which are primarily agricultural, and directed towards new and improved products. In order to effect this transition there should be techno-economic planning in certain key industries and basis utilities, and the development of managerial, technical and research services. Radical changes and a new outlook is required in the organisation of Science and Technology on a national level.

SECTION F—SOCIAL SCIENCES

Presidential Address

SOME ASPECTS OF FOREIGN AID

by

W. M. TILAKARATNA

Foreign aid is a very controversial subject. It has its fervent believers and its quota of sceptics. Nevertheless, there is no doubt that in the contemporary world foreign aid looms large in international economic relations. It is an important feature in the economic relations between the developed and underdeveloped or developing countries of the world. In the year 1965 the total of foreign aid to less developed countries was in the region of $ 11 billion.

The term foreign aid covers many types of assistance ranging from outright grants to loans on less or more onerous terms of repayment and interest. There is also military aid in one form or another given by the developed countries, especially the United States of America. I propose to leave out the entire subject of military aid from my talk because the problems associated with it and its motivations are different from what might be called economic assistance or foreign aid for economic purposes. I shall be using the term foreign aid in this talk as being synonymous with economic assistance.

Foreign aid, as indicated earlier, covers many types of assistance. First, there are outright grants given by developed countries to less developed countries. Such grants, as the term implies, are not repayable and results in an outright transfer of resources from the donor to the donee countries. Recent studies on foreign aid show that the grant component of foreign aid is tending to decline. Secondly, there are loans. The terms on which these loans are given tend to vary widely. There are interest free loans given recently, for instance, by the United Kingdom with fairly generous repayment periods. Others lend on a varying combination of terms in regard to repayment periods, grace periods and rates of

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interest. For instance, there is the Canadian soft loan programme of 1964, which gives a 50 year repayment period commencing after 10 years of grace with an interest charge of only 0.75 per cent. Belgian soft loans to Turkey were given at 3 per cent interest and a repayment period of 20 years with a grace period of 5 years. France gives official loans for 15 to 20 years at 3 to 3½ per cent interest and Government Guaranteed export credits for a maximum period of 13 years at around 5 per cent interest. German loans carry a 3 per cent rate and 20 to 25 years for repayment with a seven year grace period. The U.S. loans are given for a maximum period of 40 years with a maximum grace period of 10 years at a one per cent interest rate, and 2½ per cent interest thereafter. The Soviet Union, China and the East European countries tend to charge rates of interest around 2½ per cent and allow fairly liberal repayment periods. The rates quoted by me are purely illustrative. Bi-lateral aid pacts entered into between these countries and the less developed countries tend to carry terms which are more or less soft depending on a host of conditions including rates of interest prevailing in the donor countries.

These loans whether they be soft or hard result in a transfer of resources from donor to donee, in the first instance, but there is a backward transfer of resources in excess of the original transfer from donee to donor over the years.

There are some who argue that the term foreign aid should include only outright grants and the grant element in soft loans; that is the difference between the going commercial terms and the liberalised terms at which loans are given, converted by some method to work out the grant equivalent. In the case of food supplied under U.S. Public Law 480, popularly called PL 480 loans, their valuation for aid purposes at world market prices can also be questioned. These supplies of wheat and other food grains are from excess stocks in the U.S. which if they were released for sale in the world markets would result in a substantial fall in world prices. It is argued that if receiving countries were free to purchase their requirements in world markets in which these excess U.S. supplies were also made available, they could procure their requirements at substantially lower prices, and that, therefore, the value of PL 480 supplies should be reckoned at less than world market prices. These arguments have a high degree of validity and as a consequence some writers on the subject prefer to use the term capital flows rather than aid to describe these different types of capital transfers. I do not propose to enter into this controversial field

and shall continue to use the term foreign aid in its popular sense. Military aid, as stated earlier, will fall largely outside the scope of my talk.

I wish to clear two further preliminary points of definition at this stage. The term tied aid occurs frequently in the foreign aid vocabulary. This term is used to describe foreign aid which specifies the markets in which the donee can make his purchases. Foreign aid is tied to varying extents. For instance, recent U.K. loans specify that only certain classes of specified goods containing a given percentage of British content in manufacture can be procured under the loans. Most bilateral aid tends to be tied to specific commodities which the donor country is in a position to supply. In this sense, the same argument adduced earlier in regard to PL 480 aid can be used. These commodities supplied under bilateral tied aid programmes also constitute generally the excess products of donor countries. Their valuation at market prices can also be seriously questioned. That problem, however, need not detain us here.

The second point which I wish to clear at this stage is the distinction between commodity aid and project aid. The terms are, to some extent, self-explanatory. In the case of project aid, donors—be they countries or multi-lateral agencies like the World Bank—finance specified development projects in the recipient countries. The Norton-Bridge Hydro Electric Scheme fiananced by the World Bank, the Condensed Milk Factory at Tamankaduwa financed by the New Zealand Government and the Katunayake Air Port Project financed by the Canadian Government are examples. Commodity aid, on the other hand, is more in the nature of balance of payments support under which donor countries permit donees to purchase a specified list of commodities against a negotiated credit. The commodity aid given by a group of friendly countries under World Bank auspices to Ceylon in 1965 and 1966 totalling some Rs. 450 million are examples of commodity aid. It would be recalled that Ceylon had to control her imports drastically due to balance of payments difficulties and that these controls were applied progressively from non-essential consumer goods to even raw materials and capital goods which were desperately required to allow the economy to work even at installed capacity. Commodity aid is given under such circumstances to under-pin economic activity in the country in order to achieve rapid economic recovery held up due to a basic foreign exchange shortage.

Rationale of Foreign Aid

I have so far dealt with some preliminary aspects of foreign aid concerned mainly with introducing the terminology of aid. Let me now look briefly at the origins and motivations of aid.

Foreign aid is essentially a post Second World War phenomenon. In the past there were flows of foreign capital from the richer to the poor countries, from metropolitan to colonial countries and from some rich countries to others. The essential features of such capital flows were that they were profit motivated and were related not so much to the needs of recipient countries but to the needs of the investing countries, both as an outlet for their capital funds and as sources of supply of cheap raw materials for their growing industries. The basic difference between capital flows of the past and foreign aid appears to be in that foreign aid tends to be related in some measure to the needs of the recipient countries and is not always entirely profit-motivated.

The potentialities of foreign aid were first demonstrated by the success of the Marshall Plan in Europe and the re-construction of the war-ravaged Japanese economy largely with American assistance. It would be re-called that the war left in its wake largely disrupted and destroyed economies in Western Europe and Japan. It was possible to reconstruct these economies within a very short period by massive injections of American assistance. The success of these efforts at reconstruction of destroyed economies tended to focus attention on the possibilities of utilizing foreign aid to develop the economies of the less developed countries. Some passing comment, at this stage, would be relevant about the suitability of applying the same solution to two situations which in some ways have vastly differing features. The European and Japanese examples were those of highly industrialised countries which suffered set-backs due to war destruction. The basic ingredients of rapid growth such as technical know-how already existed in these economies and all that was required was to rapidly reconstruct broken-down factories and generally rehabilitate productive capacity. This was certainly achieved with amazing rapidity through the injection of foreign aid. Economists like Prof. Bauer seriously doubt that satisfactory results can be achieved by injecting foreign aid into the largely primitive economies of the less developed countries and have, in fact, argued that foreign aid can cause positive harm in these countries by "the pauperisation of the recipients". He continues further that "indeed by now the pauperisation of some major

recipients of aid is a reality rather than a danger. The recent economic history of India can be summed up as progression from poverty to pauperism", says Prof. Bauer.

The recognition of the possibilities of foreign aid led to the establishment of the International Bank for Reconstruction and Development, popularly called the World Bank, as an institutional device for chanelling investment funds from the richer countries with excess funds seeking investment to the capital-needy and generally poorer countries. Alongside this and other multi-lateral agencies for channelling capital the concept of bilateral aid also developed, whereby rich countries give aid directly to countries of their choice. Today, by far the larger part, over 80 per cent, of foreign aid is given on a bilateral basis. This tendency to give bilateral aid rather than aid through multi-lateral agencies is largely governed by the motives for giving aid.

The factors which motivate donor countries to allocate some part of their resources for use by other countries are many and rather complex. The economic rationale of foreign aid is rather simple and we have touched already upon it briefly. The developing countries, the vast majority of which were until recent times colonies, have achieved political independence, but this independence has not brought with it the high standards of life which their erstwhile colonial masters continue to enjoy. The rapid improvement in transport and communication facilities have tended to bring into greater relief the vast disparities in the standards of living enjoyed by the "haves" and suffered or tolerated by the "have-nots". The less developed people aspire to enjoy the "good-life" of the more developed countries. This requires vast investments of capital and vast armies of trained personnel in order to activate the development potential which exists in these countries. These are not available in adequate measure in these countries themselves and it is widely felt that the developed rich countries could help to reduce the gap in the standards of living by transfering some part of their resources of capital and manpower for use in the developmental efforts of the less developed poor countries. The economic rationale is, thus, based on recognition that shortage of capital (especially of foreign exchange) and trained personnel are critical factors inhibiting the economic development of the less developed countries.

This does not mean that there is no recognition of the existence of factors other than capital and skills which inhibit economic growth in these countries. Prof. Bauer, for instance, has argued that "material progress depends primarily on the development of suitable human qualities, attitudes and social institutions and not on the inflow of external grants of money". There are many adherents to this line of thinking. There certainly are these other factors but there can be little doubt that shortages of capital and critical skills inhibit the rapid economic growth of most developing countries. The need for enhanced supplies of capital and technical skills is acutely felt and forms the basic economic argument in favour of foreign aid.

The economic rationale of foreign aid is certainly the key motive which induces the less developed countries to seek aid; it is certainly not the only motive which induces the donor countries to give aid. The motives of donors are many. They range from the purely altruistic to the purely selfish and from economic to political motives. To some donors foreign aid is a means of increasing their spheres of political influence and a vehicle for propagating their particular species of political philosophy. Military aid is entirely in this category but I have already excluded military aid as being a class by itself and excluded it from the scope of my talk. A good many economists like Prof. Kindleberger have argued that a substantial part of economic aid is also a mere extension of the foreign policy objectives of some donors. Adherents of both major political camps of the world use foreign aid as a method of winning support of their foreign policies and, more positively, use foreign aid as a method of influencing the attitudes of recipient countries to private capital, political alignments and so on.

There is a genuine body of opinion in donor countries based purely on a recognition of deplorable economic conditions in the less developed countries. These people sincerely feel the need to help these countries to get on their feet as fast as possible to enable the mass of people living in them to lead decent lives. These altruistic motives are certainly responsible for some part of the aid flowing into less developed countries; witness, for instance, some of the small countries with no ambitions of world domination who give their aid in the form of outright grants and loans on soft terms.

The furtherance of the economic self-interest of donor countries is an important motive in the grant of aid. Eugene Black, a former President of the World Bank, for instance, has argued that aid programmes are sound investments which provide substantial immediate markets for U.S. goods, stimulate the development of new markets and orient national

economies throughout the world toward a free enterprise system in which U.S. private firms can prosper. In a very real sense the grant of aid can be motivated by and can result in the furtherance of the economic interests of the donor. Both commodity and project aid given by on a bilateral basis are tied to procurement in the donor countries. As the recipient countries are generally faced with an acute shortage of foreign exchange, this tying of aid tends to divert trade in favour of donor countries enabling these countries to maintain high levels of production and employment. Ultimately, repayment of loans and interest tend to divert resources into the donor countries.

The grant of foreign aid is not entirely motivated by economic considerations, either of the self-interest of donors or of the rapid economic development of recipients. If the latter were the criterion, rapid growth might best be achieved by giving aid only to those countries which can most effectively make use of them. For, in this way, it would be possible to achieve a more rapid rate of growth with a given quantity of aid than under the present system of somewhat haphazard distribution, which exists mainly because economic criteria are not the only ones motivating aid.

Problems of donors and recipients

Let me now look at the problems of aid giving and aid receiving countries. I had originally intended to treat the problems of donors and donees separately, but these are so interconnected that I propose to discuss them together, if not for any other reason, at least to avoid repeating myself.

It will be recalled that one of the main targets of the United Nations Development Decade was that developed countries should aim at giving 1 per cent of their Gross National Product in economic assistance to the less developed countries. This target is as yet far from being achieved. The United Nations report on International Assistance, 1961 to 1965, observed that the flow of capital aid to developing nations is still about two-thirds of the minimum target of 1 per cent of GNP set by the United Nations General Assembly. What is more significant is that the attainment of the target was further from realization in 1964 than in 1961. All reports indicate that the situation has not improved since 1964. It would be interesting to examine why the foreign aid efforts of the donor countries is falling below target.

It would appear that there has been a noticeable hardening of attitude towards aid in the developed countries. Foreign aid given to the less developed countries has not achieved the same spectacular success of the Marshall Plan, albeit for very good reasons. There has been a growing literature pin-pointing the misuse of aid in the receiving countries. At the same time, the donor countries have been faced with their own balance of payments problems. The cold war which offered the major political motivation for aid has thawed considerably. For these and many other reasons the achievement has been well below the target set for the Development Decade and that is more, as the years go by, the possibility of achieving the target seems to be receding further.

It has also been observed that donor countries tend to tie, in some sort of way, the aid given by them to procurement of goods in their respective countries. This has presumably become necessary because otherwise aid given by one country might be utilized by the recipients for purchases in several other countries creating thereby, balance of payments problems for the donor country. The aid is also generally tied to a specific list of commodities to be procured in the donor country. This has again become necessary in order to relate the demands of the receiving countries to the production capacities of the donor country. All this has limited the use of assistance offered by the donor countries because the actual use requires highly complicated procedures in order to ensure that purchases are limited to specific commodities for which the aid is given and from specified countries.

From the point of view of the receiving country tied aid creates several problems. No doubt the availability of aid adds to the total resources of the receiving country. But it does so in a manner which might not be in keeping with the development priorities of the receiving country. For instance, while projects of high national priority cannot be carried out due to a shortage of foreign exchange, tied aid could make it possible to carry out projects of low priority if the requirements of these projects could be financed through foreign aid. Then again some of the items listed for procurement in a particular country might traditionally have been procured in different markets on purely economic considerations. The availability of aid for such commodities tends to divert imports to the aid giving countries which might not be the most advantageous sources of procurement from an economic angle. There is also generally a problem of fitting the available list of aid-financed goods to actual requirements. For instance, only one or a few of several component raw

materials might be available on aid. The recipient country then finds itself in the position of having to allocate foreign exchange out of its own resources for the other component raw materials, if it is to utilize the available aid. This tends to distort the priorities in the allocation of the scarce foreign exchange resources of the recipient country. Further, where these imports are required by private firms and the prices payable on aid-financed imports are higher than usual prices, private importers tend to be reluctant to import such goods even though it may be in the national interest to accept such aid. It can be argued that the choice which the receiving country has is to procure such supplies even at high cost from non-traditional sources or not have them at all. While it is certainly true that untied aid is perferable to tied aid, it would also be true that tied aid is preferable to no aid at all.

In recent years there has been a general hardening of interest rates in the donor countries themselves which have been following deflationary policies of varying degrees of rigour in order to solve their own economic problems. These have resulted in aid becoming more expensive in terms of service charges. Whereas in past years, it was possible to borrow in the world markets at rates of interest of around 4 per cent, today rates of interest tend to be at levels of 6 per cent and above. While some donor countries subsidise to some extent the interest cost of foreign aid, there has certainly been a general increase in the cost of borrowing. These high interest rates are symptomatic of a general sqeeze on resources in the developed countries and they create a problem of high cost of foreign aid for the developing countries. It has been observed that the big question mark in regard to the aid effort today is whether it will survive the Atlantic World's drift towards competitive deflation.

I have already referred to the growing literature on the question of aid utilization. The public of donor countries have been fed on horror stories of the misuse of aid. Books like the *Ugly American* and the *Nation of Sheep* come to one's mind. Instances of aid given by the donors flowing freely into the private pockets of contractors, blackmarketeers and so on, have been highlighted. All these have tended to create in the donor countries, especially democratic countries, a growing feeling that aid given at a sacrifice of their resources, is not being utilized properly and that what is now required is not more aid but greater supervision of the utilization of aid. It would appear that receiving countries would find it rather difficult in the future to escape some kind of surveillance by donors of the utilization of aid. This would again create problems for the receiving countries in that their economic activities will come under supervision by outsiders.

There is a growing body of public opinion which favours the increased use of multilateral agencies rather than bilateral arrangements. Increased surveillance by outsiders of the utilization of aid in developing countries could very well lead to the aid being channelled through multilateral agencies rather than on a bilateral basis. It is, at least, likely that the receiving countries would tend to agree to surveillance only if it is done through multilateral agencies and not by individual donor countries.

It has been observed that the developing countries which are by and large exporters of primary products tend to lose the benefits of aid through a worsening of their terms of trade vis-a-vis developed countries which are largely exporters of manufactured goods. The donor countries appear to be getting back by way of cheaper imports and dearer exports as much or more than the aid they give to the developing countries. The United Nations Conference on Trade and Development, UNCTAD, as it has come to be called, served to focus attention on the trade problems of the developing countries. There is a feeling that trade is more important than aid and that the developing countries could manage on their own without aid if they can get better prices for their exports. Indeed, these problems assume great significance in the context of the chronic balance of payments problems which developing countries are likely to face for many more years.

I have already drawn attention indirectly to the balance of payments problems of aid giving and aid receiving countries. It would be relevant at this stage to focus greater attention on this problem. Aid involves the transfer of resources from the donor countries to recipients and the repayment of the capital and interest involves the transfer of resources from donee countries to donor countries. Both transfers of resources can be a strain on their respective balance of payments. In fact, one of the major reasons why the flow of aid is not higher is that the donor countries are themselves faced with balance of payments problems and find it difficult to bear the additional strain of giving aid. On the other hand, aid in the form of loans, which is by far the major component of aid, raises problems of the capacity of recipients to service their loans. In fact, it has been estimated that some aid-receiving countries pay back annually by way of service charges, about half the new aid that is

received. In the past, several countries have had to go in for consolidation due to their inability to meet commitments. The cases of Argentina, Brazil, Turkey, Chile and Ghana are well-known examples.

Developing countries have to be cautious and ensure that their economies will not become heavily indebted to foreign countries without, at the same time, depriving themselves of the loan capital much needed for their development. In the utilization of foreign aid, they must be careful to see that sufficient capital formation takes place in their countries, so that future production would increase export earnings or save import expenditures adequate to meet the commitments on these loans. From this angle, foreign aid received purely as additional balance of payments support can create dangerous problems for the future unless foreign exchange resources including aid are carefully allocated with a view to increasing the productive capacity of the economy rather than to enhance current consumption. The danger is a real one; recipient countries should be constantly aware of it. The very objective of aid is to enable developing countries to do without aid sooner or later, the sooner the better. It is also necessary to emphasise, in this connection, the fact that aid flows are not necessarily regular and continuous. India found herself in difficulty when aid was suspended due to the Indo-Pakistan war; this can happen to other countries as well, so that, reliance on increasing flows of foreign aid in the future in order to meet commitments on current aid flows as well as to sustain the tempo of economic growth can indeed be very dangerous.

The general problem of international liquidity has had great airing of late and solutions involving the creation of additional international liquidity for purposes of enhancing aid flows have been suggested. In regard to aid the problem of liquidity is a two-fold one. As stated earlier, the granting of aid can constitute an additional strain on the balance of payments of donor countries. Similarly, the repayment of loans and interest payments constitute a very real burden on the scarce foreign exchange reserves of the developing countries. There seems to be a possible line of solution to this problem. It might be possible to allow donor countries a contingent drawing right at the International Monetary Fund calculated as a proportion of the actual amount of aid disbursed in a given period of time. This drawing right should be available purely for settlement of balance of payments deficits with other donor countries. There must be some agreement amongst donors to accept drawing rights with the Fund in settlement of deficits, perhaps, upto certain specified limits. This would also enable donors to give untied aid without serious balance of payments repercussions. Similarly, the developing countries should get additional drawing rights for actual capital repayments. This would enable developing countries to meet their obligations and to recoup, if necessary, the resulting loss of foreign exchange through a temporary borrowing from the Fund. Thus any undue and unforeseen strain on their balance of payments arising from loan repayments can be overcome temporarily.

I would like to conclude my address on a note of caution. It has been aptly said by H. Myint in his book *The Economies of Developing Countries* that "... however generous the supply of foreign aid, it can only relieve the harshness of choices rather than abolish the basic economic problem of having to make choices. This is particularly true when it is remembered that in many underdeveloped countries the basic 'scarce factor' may not be the shortage of earning but the ability to absorb and invest capital effectively". This serves to emphasise that while foreign aid might conceivably be a necessary condition for the rapid economic growth of the developing countries it is not a sufficient condition. Economic development is a complex process and if a whole host of other factors combine to provide an appropriate climate for economic growth, foreign aid can be a source of additional resources. It can never be a substitute for those other factors, which can be made favourable for growth only by the efforts of the developing countries themselves.

Aid can only supplement national effort, it can never be a substitute for it.

LECTURE BY CHIEF GUEST

MATTER AND THE UNIVERSE

by

Professor C. F. Powell

Introduction

In this address I want to give an account of recent developments in two of the most significant and penetrating branches of modern science, particle physics and cosmology, for scientists not specialist in the field. I shall show that we are beginning to enter a radically new layer in the structure of the material universe and that the consequences are likely to be not less profound than those which have always followed similar advances in the past, not only for natural philosophy and our deeper understanding of the constitution of matter, but in the long run for the whole body of science and practice.

It has always in the past been difficult to assess the implications of fundamental advances in science in their early stages, for we tend to be bound by the horizons of our own times. Thus it took 50 years for Faraday's experiments on electro-magnetism to reach practical fruition. A second example is provided by the developments of the 1920's and 1930's which saw the birth of the quantum mechanics and the incorporation within its framework of the theory of relativity. The concepts which were then introduced seemed strange and esoteric at the time, and of no practical importance, but they have now pervaded the whole of science. The discoveries of which I am to speak will, I believe, not be of less decisive consequence and will one day provide the new foundation of everything we do.

From the time of classical antiquity it has commonly been assumed that there would one day be an end to the process of delving deeper into the nature of matter—'atom' means that which cannot be cut—but such a position can no longer be asserted. In the light of the discoveries of the past 30 years, we may now reasonably suppose that there is no limit to the process of discovery in this field.

Cosmology and the structure of matter

Both cosmology and the structure of matter are ancient themes in natural philosophy, deriving from classical antiquity, but during the past 100 years there has been a particularly intimate connection between them. Let me remind you of the important controversies relating to the age of the earth and the age of the sun. You will remember that Kelvin estimated the time it would take for the earth to cool, from a primaeval state at very high temperature, to its present condition. He reached the conclusion that it could not be more than a few million years old. Such a time-scale was completely unacceptable to the geologists who from the record of the rocks demanded periods of the order of hundreds of millions of years as essential for the pattern of the evolutionary process.

The dilemma was resolved by the discovery of radioactivity and the presence of radium, uranium and the radioactive isotope of potassium in small concentrations in the surface layers of the earth. Their decay provides a source of energy some of which is degraded into heat which provides the earth with a kind of electric blanket—a device which is not, I am sure, much employed here—which completely vitiates Kelvin's calculations. Kelvin never acknowledged the significance of radioactivity. Perhaps he had become too personally involved in the controversy easily to withdraw. Certainly he could have avoided embarrassment if in his earlier papers he had made the reasonable proviso that his calculations were dependent upon the fundamental assumption that there were no hitherto unrecognised sources of heat in the earth's crust.

A second example, more important for our present theme, is the age of the sun. If the processes in the sun which provide for the outpouring of energy which sustains life on earth were based upon ordinary chemical reactions then its radiating life would again be quite insufficient for the very long time scale, of the order of 10^9 years, required for biological evolution.

Energy generation in stars

It was only in the 1930's that detailed theories of the energy generation in stars began to be elaborated which allowed a serious understanding of the ways in which, in the interior of stars, energy is provided by the conversion of mass. We now know that this occurs during the main radiating life of a star through a series of nuclear reactions which lead to the conversion of hydrogen into helium, by the carbon cycle or the direct proton-proton reactions, so that we can account for the long life of stars like our sun; viz $\sim 13 \times 10^9$ years.

The detailed understanding of the nuclear origin of stellar energy allows us to predict the characteristics of stars in a way so consistent with observations on stellar populations that we may have great confidence in their essential correctness. The history of a particular star is largely determined by the mass of the gas cloud from which it condenses. As it contracts under gravitation, the central regions of the gas ball increase in temperature until thermal nuclear reactions begin and supply energy at a rate which balances the loss by radiation from the surface regions.

Thereafter the star evolves relatively slowly, consuming its hydrogen in the central core and gradually converting it into helium. The nuclear processes produce about a million times more energy than chemical processes for the consumption of a given mass of fuel so that the main radiating life of our sun is about 13×10^9 years and amply sufficient for providing conditions in the surface of the earth for life to emerge. The greater the original mass of a star, however, the higher the central temperatures, the brighter the star, the hotter its radiating surface, the more rapid its evolution, and the shorter its life.

These features are illustrated in Fig. 1, in which the predicted luminosity of a star during its main radiating life is plotted against its surface temperature—a form of the Herzsprung-Russel diagram. The corresponding lifetimes in the main sequence and the mass of the star are also indicated.

The details of a star's history depend to some extent on the precise chemical constitution of the matter of which it is composed; the extent for example, by which the main constituent, hydrogen, is accompanied by small admixtures of heavier elements formed in the life and death of previous generations of stars where matter, already processed in a star, is ejected into space so that it can provide material for the formation of later generations. If, however, as in a 'globular cluster' the stars of a large group are formed from a common, relatively homogeneous, source of material at a nearly constant distance from our point of observation, the regularities among the component stars can be shown to be remarkably precise; an example is shown in Fig. 2. Fig. 2 shows the grouping of the points about the 'main-sequence'. There are very few stars in the

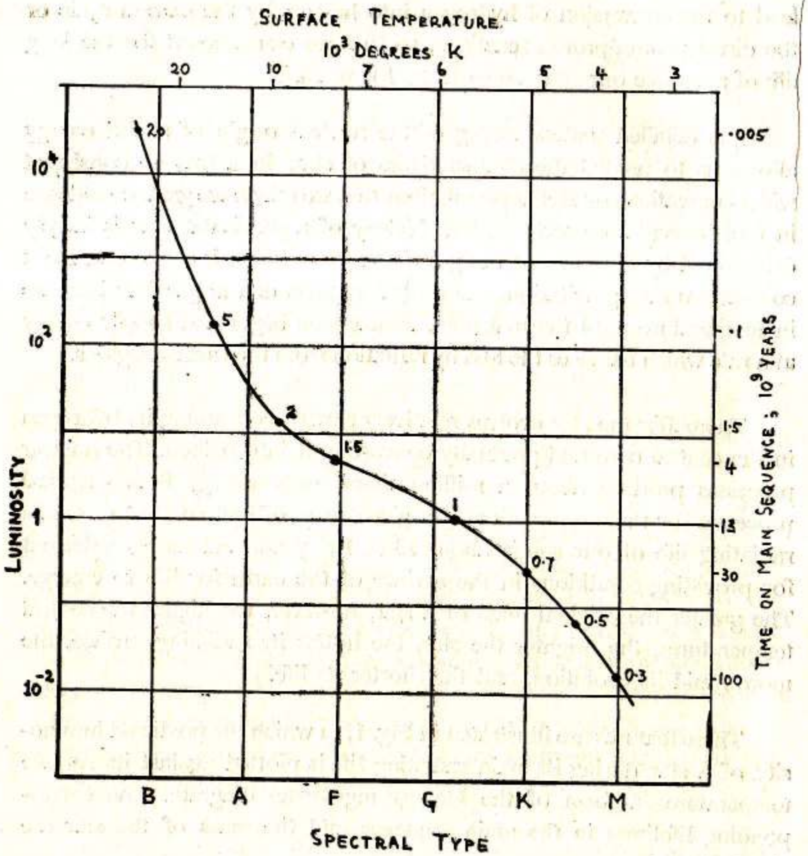

Fig. 1

Herzsprung-Russel diagram showing the predicted luminosity of a star against its spectral type when on the main sequence. The figures attached to the points show the mass of the star compared with that of the sun, $M_{\odot}$. The corresponding values of the surface temperature of the star, and its predicted lifetime on the main sequence are also indicated. The luminosity is expressed as a ratio to that of the sun on a logarithmic scale.

main sequence with a luminosity greater than the point shown by the arrow, associated with the fact that the brighter, more massive, stars have ended the period of their life on the main sequence and evolved away from it. The upper limit of brightness in those stars in a globular cluster which still lie on the main sequence therefore allows its age to be estimated.

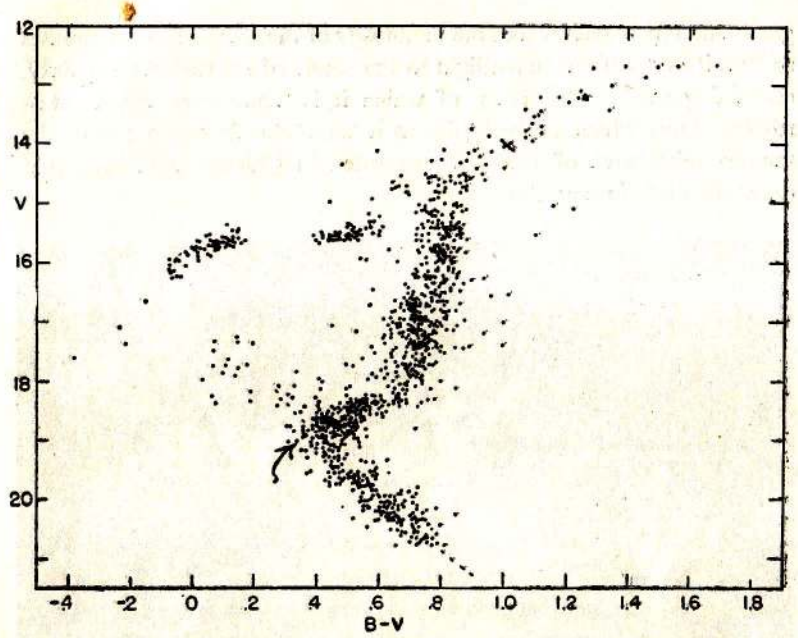

Fig. 2

Herzsprung-Russel diagram for stars in the globular cluster M3. The plot shows, for any star, its relative magnitude as observed in ordinary light against the difference in magnitude in blue light and in ordinary light, the latter quantity giving a measure of the surface temperature. The grouping shows the divergence of the more massive stars away from the main sequence into the region of the red giants and the subsequent stages in stellar evolution (after Johnson and Sandage).

At a certain stage in the history of some heavy stars energy production then proceeds by the 'burning' of hydrogen in a relatively thin region at the periphery of this core, and the point representing the star on the Herzsprung-Russel diagram moves away from the main sequence; its luminosity increases at the same time as its surface temperature falls and it becomes a red giant. Later, following further contraction, the core temperature reaches such a high-value, $\sim 10^8$ °K that reactions involving helium set in and lead to the synthesis of heavier nuclei such as O^{16}, Ne^{20} and Mg^{24}. These provide relatively transitory new energy sources and the point representing the state of the star on the Russel-Herzsprung diagram departs widely from the main sequence; see fig. 1. Further transient stages follow and the whole edifice soon reaches a stage, with the establishment of very high temperatures $\sim 10^9$ °K in the core and the condensation of much of the matter there into the nuclei of iron, where, for some stars at least, a spectacular evolution occurs. There is a sudden release of very great amounts of energy and the luminosity of the star suddenly increases so that it may emit as much light as the whole of the rest of the galaxy, containing $\sim 10^{10} - 10^{11}$ stars, of which it is a member, and a catastrophe occurs which we recognise as a 'super-nova'. The relicts of the famous super-nova of 1054 AD, recorded in Chinese annals for that date, is shown in Fig. 3.

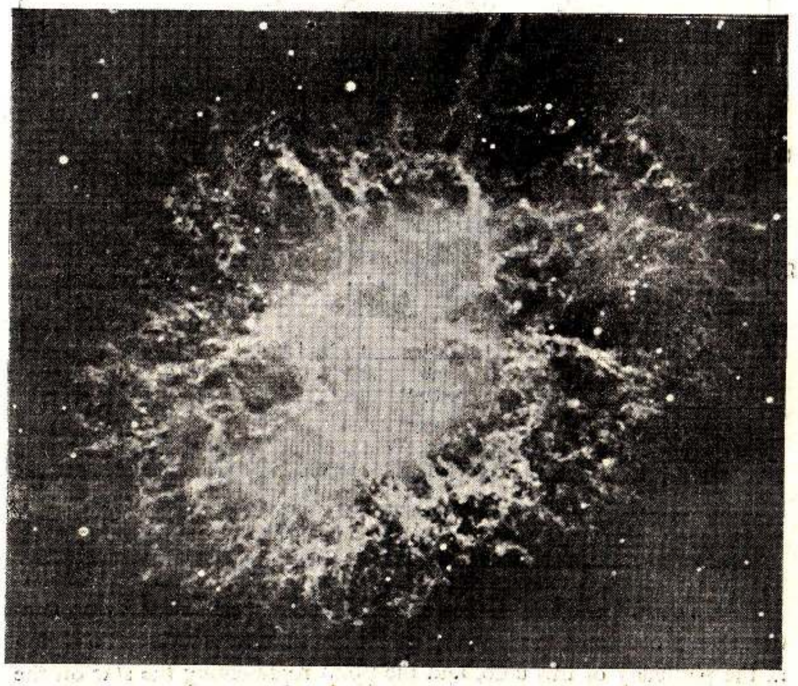

Fig. 3

Photograph of the Crab nebula, the relict of a supernova explosion, recorded in the Chinese annals for 1054 A.D. The detailed structure was made visible by photography in red light which allowed the hydrogen line Hα to predominate. The nebula is about 3000 light-years away.

Generation of heavy elements

It is in the stage of the 'super-nova' that a star, over a period of a few seconds, acts as a great furnace for the creation of the heavy elements. At this time there is a rapid generation of large numbers of neutrons which rapidly build up heavy nuclei by neutron accretion. A succession of neutrons enters a nucleus so that its mass number, A, rapidly increases, at constant charge number Z. There is a limit to thisprocess, and the increase in mass which can be achieved, unless by a process of β-decay

the emission of an electron and a neutrino, the charge number Z changes to $Z+1$, etc.; but when this occurs, further accretion can follow. We are thus able to account in a large measure, for the relative abundances of the different nuclear species as we find them on earth and in the general matter of the universe, and for the occurrence of the heaviest elements.

In an important class of supernovae, the observed diminution in the luminosity of the star following the explosion corresponds to an exponential decay with a half-value period of about 55 days. The reason for this particular period was quite unexplained until it was realised that, within the limits of error, it is equal to that of the isotope of californium of mass number 254. This particular isotope decays by spontaneous fission and thus releases a large amount of energy per disintegration so that, whilst it lasts in appreciable concentration, it is the main producer of energy in the star immediately following the super-nova outburst, although other transuranium elements with similar characteristics may also contribute. It is reasonable to suppose that we are seeing here a remarkable demonstration of the manufacture of the heaviest elements at the instant of the explosion, for which other evidence has recently been obtained in experiments in cosmic radiation of which I shall speak in my third lecture.

The success of this theory of nuclear genesis gives us further confidence in the essential correctness of our picture of the structure and energy generation in stars and some of the main features of their life history. For our present purpose, it is important to emphasise that as the mass of a star increases its main radiating life rapidly decreases so that a star of fifteen solar masses has a life-time of less than 10^7 years; and for a star of 30 M_0, less than $\sim 10^6$ years. With further increase in mass we should expect a further rapid reduction in the lifetime.

Quasars and Exploding Galaxies

Against this background, recently discovered astronomical objects which show properties exceedingly difficult to explain in terms of the kind of processes which we confidently believe to account for energy generation in most of the stars, appear to be of great importance. These are 'quasi-stellar radio-sources' or 'quasars', together with objects like the exploding galaxy M.82 shown in Fig. 4. The actual nature of the quasars, their distances and rates of emission of energy, remain to be determined and it will be convenient to consider the exploding galaxies.

The remarkable features shown by a study of M.82 may be briefly summarised as follows:—It is a very powerful emitter of radio waves

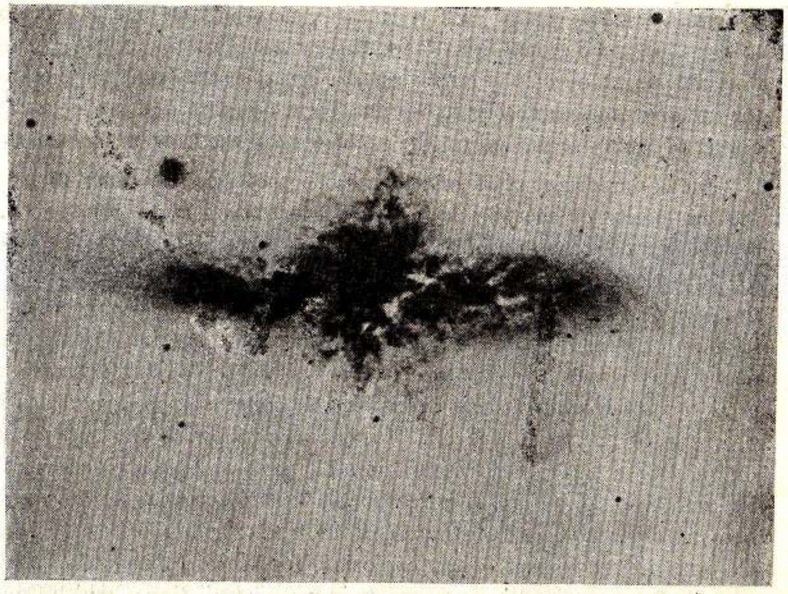

Fig. 4
Photograph of the galaxy M.82 made by A. R. Sandage with the 200 inch telescope at Mt. Palomar. In the original photographs the filaments due to the outward movement of hydrogen can be clearly distinguished out to distances of about 14,000 light years.

and most of the light in the ultra-violet emitted from the galaxy is polarised, strongly suggesting that it is produced by synchrotron radiation, by fast electrons constrained to move in curved paths in magnetic fields.

We are now familiar with this kind of radiation because it is emitted by the very energetic electrons as they are generated in the great circular electron accelerators, such as the electron synchrotron. The rate of loss of energy suffered by an electron beam from this cause rises rapidly with the energy of the electrons and sets a limit to the maximum energy of the beam which such machines can generate without a very large input of power to compensate for the loss.

Another remarkable feature of M.82 are the hydrogen 'filaments', as shown by spectral analysis, streaming out from the central regions of the galaxy for a distance of 14,000 light years.

Synchrotron radiation shows a continuous spectral distribution extending from the radio-region into the far ultra-violet and we can compute the energy of the circulating electrons in the magnetic fields

prevailing in a galaxy, which are believed to be of the order of 10^{-6} gauss. To generate the observed radio-emission in such a field would require electrons of energy from about 1 to 25 GeV, where 1 GeV equals 10^9 electron-volts; the observed ultra-violet light would require electrons of $\sim 10^4$GeV. The mass moving out from the central regions of M.82 is estimated to be of the order of 5×10^6 solar masses with a total energy of motion of $\sim 2 \times 10^{55}$ ergs. The total energy, E, in M.82 is estimated to correspond to 10^{57} or 10^{56} ergs, whilst in other objects E is estimated to be as high as 10^{62} ergs. Making reasonable estimates of the efficiency with which energy released in nuclear processes can be transformed into radio-emission, it appears that to produce 10^{62} ergs would require the consumption of 10^{10} solar masses.

I quote these figures in order to emphasise that it appears impossible to account for objects like M.82 in terms of the conventional picture of energy generation in stars; and although their precise nature remains to be established, it seems that the 'quasars' also present a similar difficulty. We have at present no understanding of the greatest energy sources in the universe which appear to transcend nuclear processes by as much as nuclear sources exceed chemical sources of power.

Deeper layers in the structure of matter

In this situation, recent advances in particle physics appear to be very significant. Briefly, we can now be confident that there is a deeper structure in matter which we are beginning to unravel. The particles which we used to think of as elementary, we now believe to be composed of more fundamental units. These sub-units must be bound together by forces immensely more powerful than the 'strong forces' which hold together the protons and neutrons in a nucleus and which are responsible for energies released in nuclear reactions.

The evidence for these sub-units is not yet decisive and their independent existence remains to be established, but what is known is highly suggestive and presents similarities to the situation, about a hundred years ago, when Mendeleef arranged the chemical elements in an ordered sequence, the Periodic Table. This allowed him to predict the existence of missing members, the atomic weights and chemical properties of which he was able to anticipate, and which were subsequently discovered. It was reasonable to anticipate that the regularities in the Mendeleef Table were evidence for an underlying order, but it was sixty years before the discovery of radio-activity and the establishment of the nuclear structure of the atom allowed a simple explanation of the regularities in terms of the nuclear atom.

During the past twenty years, and at an increasing rate during the past ten, we have discovered the existence of a large number of different 'elementary' particles, not less fundamental than the proton or the neutron; there are now about 150 of them. Most of them are very ephemeral with mean lifetimes which are sometimes as short as 10^{-21} secs, and after a brief existence they transform spontaneously into other lighter particles with the appearance of an amount of energy—of motion, for example, equivalent to the amount of mass which disappears.

Fig. 5 shows some of the particles now known in a representation in which the charge and the mass of the individual particles are displayed. Important groupings may immediately be distinguished:—To every particle there exists an anti-particle of precisely the same mass, but with the opposite electric charge in the case of charged particles; and with an opposite magnetic moment with respect to the spin of the particle for both those which are charged and those which are neutral.

In addition it may be seen from fig. 5 that there are groupings of particles of the same mass, but of different charge. The neutron and the proton, for example, form a 'doublet', one neutral and one positively charged, +e. There is difference in mass between them, but it is too small to be shown on the scale of the diagram, and this is true of most of the groupings, such as the 'quartet' of particles with a mass of about 1240 MeV. These groupings of particles of nearly the same mass are regarded as different charge-states of the same entity; we regard the neutron, and the proton, for example, as two charge-states of the nucleon; and the group of mass 1240 MeV as the four charge-states, -e, 0, +e, + 2e, of a single type of a particle, which we refer to as N*.

In describing the properties of the different particles, and their interactions with one another, we find that we are forced to attribute to them new characteristics, new quantum numbers, in addition to the familiar ones such as mass, charge, spin and magnetic moment, which are derived from our experience of the world on a macroscope scale. Thus it is found convenient to ascribe to a group of particles, such as the neutron and the proton, quantities which we call the I-spin and the hypercharge, Y. The hypercharge is defined as twice the mean charge of a group. Its value for the nucleons, for example, is $2\,\frac{(0+1)}{2} = 1$; whilst for the group of mass 1240 MeV, it is $2\,(\frac{-1+0+2+2}{4}) = 1$ also. The term I-spin is derived by an analogy with ordinary spin:—

In the treatment of 'spin' in quantum mechanics, a particle is characterised by an intrinsic 'spin' quantum number S, which may be either integral or half-integral; for electrons, for example, $S = \frac{1}{2}$. The angular momentum of such a particle is of magnitude $\sqrt{S(S+1)}\,\hbar$ where $\hbar = h/2\pi$, h being Planck's constant. If we attempt to determine the magnitude of the angular momentum of a particle with respect to a particular direction, such as may be provided by a magnetic field, we find that only a limited number of values, 2S + 1, are possible; two values $+\frac{1}{2}\hbar$ and $-\frac{1}{2}\hbar$, for an electron for example, $2(\frac{1}{2}) + 1 = 2$. These values of the observed components of angular momentum with respect to a defined direction are often referred to as S_3, the 3rd component of the 'spin'.

By analogy we regard the different charge-states of a particle as manifestations of different settings of an intrinsic I-spin or isotopic 'spin', so that if we find two such states, the I-spin is $\frac{1}{2}$; if four, $I = \frac{3}{2}$, etc. Thus the value of the I-spin for the nucleous is $\frac{1}{2}$; they therefore form a doublet of which the value of I_3 for the proton is $+\frac{1}{2}$; and for the neutron, $-\frac{1}{2}$. Of course the connection between I-spin and the number of charge-states as here presented appears trivial, but I-spin plays an essential part in the description of many details of the behaviour of particles.

A third parameter essential to the description of a particle is its parity. In quantum mechanics the state of a particle is described by a state-function which may contain functions of the geometrical coordinates x, y, z. If this function is unchanged when the coordinates are changed to -x, -y and -z, the function is said to have even 'parity'; if it changes in sign but not in magnitude, it is of 'odd' parity. We find it necessary to attribute an intrinsic parity to any particle, even or odd, in order to describe it; it is one of the symmetry properties of the particle, essential to its description, which we can determine by experiment.

Order among the elementary particles

We are now in a position to appreciate the observed order among the particles. If we choose a group of particles with a given spin and parity, and in a certain range of masses, we find that they form an ordered array. An example may be seen in fig. 5 where a group with spin $\frac{3}{2}$ and positive parity have been separately distinguished by the symbol ● The triangular pattern, with four particles of hypercharge Y = +1 in the lower rank, and three, two and one in the ranks at successively higher masses, is immediately apparent together with the apparently constant difference in mass between the ranks.

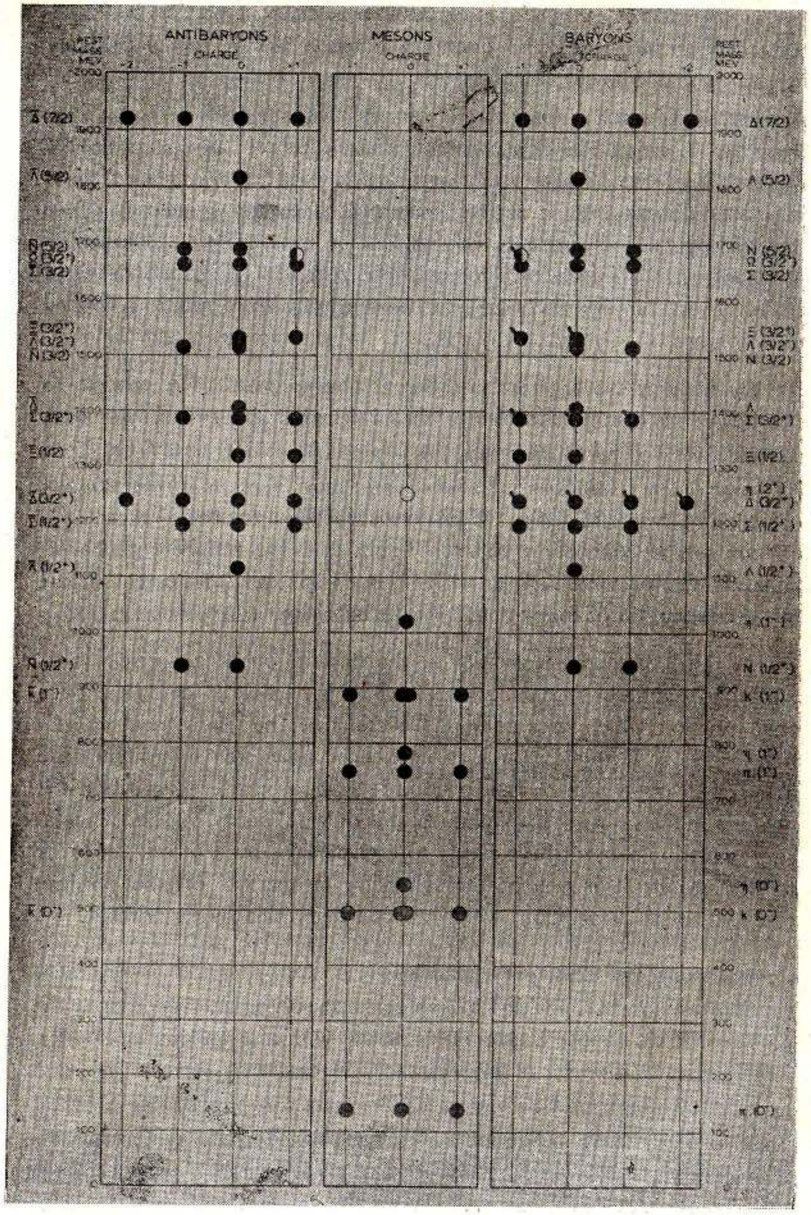

Fig. 5

We may represent the same group of particles in a different way by plotting for each member the value of its hypercharge against the value of its I-spin, I_3, by choosing appropriate scales for Y; see fig. 6. We then find a pattern, striking symmetrical about three axes marked U_3 V_3 and T_3. All particles on lines parallel to the U_3-axis have the same charge; all those parallel to the T_3-axis, the same hypercharge. Such regularities were recognised before the discovery of the particle Ω^- of Y = -2, I = 0. They led to the prediction of its mass, its possible modes of creation in the collision between other particles, and others of its properties; a search was made in the light of these predictions and its existence was soon established. Twenty unambiguous photographs showing the creation and decay of the particle have now been obtained.

The above example shows the ordered array of ten particles, a 'decuplet' of particles. Five other grouping each containing eight particles are now known including two octets composed of mesons and three of baryons, each group with its own distinctive value of spin and parity, so that the analogy with Mendeleef is substantial and highly suggestive.

Early attempts to account for these regularities showed that it was possible to describe many features of the observations by regarding all the members of the recognised groups of baryons as built up of three sub-particles each of spin $\frac{1}{2}$ ℏ, which could exist in any one of three possible states. An example of an explanation of the decuplet already referred to is set out on fig. 6.

The successes of such theories, though incomplete, were impressive and attempts were made by studies of cosmic radiation and in work with the great accelerators to detect their independent existence. These

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Caption to Fig. 5

Representation of some of the known particles of lowest rest-mass, of which the quantum numbers are established, in a diagram in which the mass is plotted against the charge. The electrons, neutrinos and muons have been excluded. There are three main groupings, baryons, mesons and anti-baryons. To any baryon there exists an anti-baryon, of the same mass and spin, but of opposite electric charge and magnetic moment. The particles are clearly grouped in multiplets of almost the same mass but of different charge, such as the nucleons of mass ~ 937 MeV, marked N ($\frac{1}{2}^+$) spin $\frac{1}{2}$ℏ; positive parity). The number in such a multiplet determines the I-spin (2I + 1), so that for the nucleons I = $\frac{1}{2}$. Similarly the hypercharge Y, twice the mean charge of the multiplet, determines the individual charges of the particles composing it; for the nucleons Y = 1, the mean charge is $\frac{1}{2}$, and the individual charges 0 and + 1e. Any multiplit with a given value of I and Y is given a symbol eg. ; Compare the quartets at masses ~ 1240 MeV and ~ 1920 MeV. The grouping of ten particles, the decuplet, referred to in the text are distinguished thus .

attempts have hitherto been unsuccessful but they allow a lower limit to the mass of the suggested sub-units, sometimes referred to as 'quarks', to be estimated. It appears that a quark must have a mass of at least 4 proton masses, so that, on this view, a neutron is composed of three sub-particles which have a total mass at least twelve times greater than that of the particle which they coalesce to form.

In a process in which quarks condense to form the nucleous of our familiar matter there would then be a release fo energy equivalent to at least ten times that of the product. By comparison, in the processes leading to the condensation of four protons into helium nuclei in the nuclear processes occurring in the stars, the reduction of mass is only about one per cent of that of the product. It follows, if this view of the composite nature of the nucleons has indeed some foundation in reality, that the forces acting between the quarks are enormously greater than

Fig. 6.

Description of a decuplet of particles, each of spin 3/2 ± and positive parity in terms of combinations of three 'quarks'

Let each 'quark' have spin ±/2 and the following values of I_3, the third component of the I-spin, and of Y, the hypercharge.

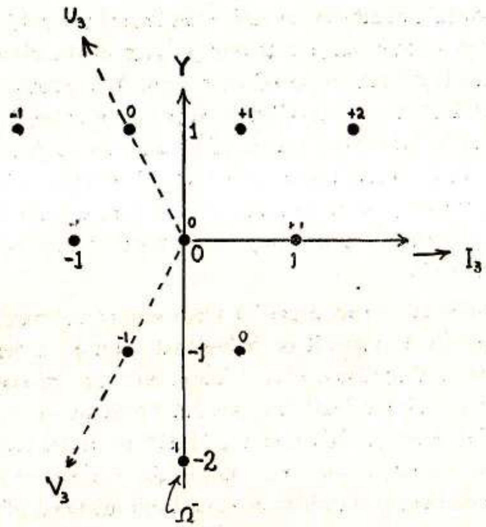
	I_3	Y	Q
State 1	$+\frac{1}{2}$	+1/3	2/3
State 2	$-\frac{1}{2}$	+1/3	−1/3
State 3	0	−2/3	−1/3

The charge, Qe is given by the relation $Q = T_3 + Y/2$ So that the quarks carry fractional electric charges $+ 2/3^e$ and $-1/3^e$

There are ten symmetrical combinations of these three quarks. The values of I_3, Q, and V_3, for each is given by simple addition of the corresponding quantities for the three components, where V_3 is given by $V_3 = I_3 - 3/2_Q$

State	I_3	Y	Q	V_3
1 + 1 + 1	+3/2	+1	2	−3/2
1 + 1 + 2	$+\frac{1}{2}$	+1	1	−1
1 + 1 + 3	1	0	1	$-\frac{1}{2}$
1 + 2 + 2	$-\frac{1}{2}$	+1	0	$-\frac{1}{2}$
1 + 2 + 3	0	0	0	0
2 + 2 + 2	−3/2	+1	−1	0
2 + 3 + 2	−1	0	−1	$+\frac{1}{2}$
3 + 3 + 1	$+\frac{1}{2}$	−1	0	$+\frac{1}{2}$
3 + 3 + 2	$-\frac{1}{2}$	−1	−1	+1
3 + 3 + 3	0	−2	−1	+3/2

Corresponding values of Y and I_3 are plotted in the figure and show the decuplet of particles inverted as compared with the mass distribution shown in fig. 5.



Points on lines parallel to axis marked U_3 correspond to particles with the same charge and other electro-magnetic properties; parallel to I_3 to particles with the same value of I-spin and hypercharge Y.

those involved in the so-called 'strong' forces which give cohesion to the atomic nuclei; and that we are here entering a radically new domain of the physical universe.

When I was a young man, Einstein was engaged in an attempt to produce a generalised field theory which would embrace both gravitation and electro-magnetism. Such a theory will remain a fundamental goal of natural philosophy, but today such an attempt would have to embrace not only gravitation and electro-magnetism but also the so-called 'weak' forces which act between electrons, neutrinos and heavier particles and are responsible for radioactive β-decay, together with the 'strong' forces which operate between the nucleons and the baryons to provide nuclear cohesion and other important phenomena. Of this last field we still know very little, but already on the horizon we see the possibility of establishing the existence of new fields of which at present we know nothing. Forty years ago, again, we were still thinking that there is an ultimate structure in matter which we could elucidate and that there would one day be an end to the process of delving ever more deeply into nature; 'atom' means that which cannot be cut. Today we seem to be faced with a vista of unending discovery—delving layer after layer into the strange structure of the material universe.

There is a certain innate conservative tendency in our thinking which makes us slow to acknowledge that our present world view is no less fragile and transitory than those of past ages. We cannot, of course, fail to see the rapid advancement of knowledge and practice, for it is occurring daily around us. But we tend to think and act, at least implicitly, as if the fundamental corner stones of our world outlook, of our natural philosophy, will persist unchanged and will not be radically transformed to provide a new foundation for everything we think and do, for all our science and technology.

It seems to me that the evidence from astronomy and particle physics which I have described makes it probable that we are on the threshold of great and far-reaching discoveries. I have spoken of processes which, mass for mass, would be at least a thousand times more productive of energy than nuclear energy. This would not be likely, as far as we can see, to provide a new terrestrial source of power, for the energy has already been lost in the condensation which produced the nucleons of our world. But it seems that there are prodigious sources of energy in the interior regions of some galaxies, and possibly in the 'quasars', far greater than those produced by the carbon cycle occurring in the stars and we have no understanding at present of their nature and origin; we may one day learn how to employ them.

Let me, in conclusion, quote to you some remarks made by Clerk-Maxwell in his first introductory lecture upon his appointment as the first Cavendish Professor Physics, hundred years ago:—

"The mind of man is not, like Fourier's heated body continually settling down to a state of quiet uniformity, the character of which we can already predict. It is rather like a tree shooting out branches which adapt themselves to the new aspects of the air towards which they climb; or roots which contort themselves among the strange strata of the earth into which they delve. For us who breathe only the spirit of our own time, and who know only the characteristics of contemporary thought, it is as impossible to anticipate the general tone of the science of the future as it is to predict the particular discoveries it will make. Experimental science is continually revealing to us new features of natural processes and we are thus compelled to search for new forms of thought to describe them".

They show a remarkable insight and are most appropriate for our present situation.

LECTURE BY CHIEF GUEST TO SECTION E

THE CHANGING NATURE OF SCIENCE

by

Professor C. F. Powell

(*Chief Guest*)

There are some aspects of science which are unchanging. It is an unending search to understand the world around us; it continually, and never so rapidly as in our own times, transforms our whole society by its profound effects on technology and the creation of radically new industries. It always exerts a profound fascination on those who are really devoted to it, so that the words which Erasistratus wrote more than two thousand years ago ring in our ears today:—

"Those who are altogether unaccustomed to investigation, are, at the first exercise of their intelligence, befogged and blinded, and quickly desist owing to fatigue and failure of intellectual power, like one who without training attempts a race. But he who is accustomed to investigation, twisting and turning in all directions, and worming his way through, does not give up the search, I will not say day or night, but rather his whole life long. He will not rest, but will turn his attention to one thing after another, which he considers relevant to his problem until he arrives at its solution".

But if science is the great creator of new industries it is no less true that technology has a profound influence on science, for industry and technology provide us with the tools of research which need to be ever more powerful. There is therefore a most intimate connection between science and technology, a symbiosis, and one of the crucial problems of our times is to ensure their balanced development; for a deficiency in one sector weakens the whole front of advance. Without good science, industry lacks powers of innovation, without good technology science must be poverty stricken and therefore lacking in creative power. In speaking of the changing nature of science, I want to illustrate my theme by considering the profound changes in the methods and scope of particle physics which have taken place in my lifetime and to emphasise the role of technology in this process. To do this I shall try and give my impressions of work in the subject roughly in three periods, the 1920's, the 1940's and the 1960's.

I was a young research student in the Cavendish Laboratory in the middle 20's when J. J. Thomson was coming to the end of his active career. Thomson's apparatus was in the basement of the building under the care of his personal assistant Everett. It was a precarious and elaborate structure of glass tubing, with discharge-tubes, Töpler pumps and McLeod gauges, dripping with the red wax employed for sealing leaks. Thomson's apparatus was, I suppose, representative of the techniques of fifteen or twenty years earlier; soda-glass was employed throughout; to exhaust a vessel was a long labour with the Töepler pump, raising and lowering the mercury reservoir; and there was no continuous measurement of the pressure, only an occasional observation with the McLeod guage which itself took a minute to make. To produce a really leak-free apparatus with such equipment was a labour of Hercules, and it was said that Everett was always nervous and apprehensive when Thomson, who was a little clumsy in handling equipment, got anywhere near the apparatus.

In this period, Rutherford was at the height of his powers and had recently established the artificial disintegration of some of the light elements by α-particles from radioactive sources. I remember my feeling of astonishment when, whilst still at school, a friend of mine who had left a year before, came back to tell us that Rutherford had transmuted nitrogen into oxygen. It was my first experience of having cherished and fundamental ideas upset by the process of discovery. Later, of course, we became used to it. But at the time all the text-books on chemistry emphasised the permanent nature of the chemical atoms; and all our teachers lived in the climate of opinion of their youth when Maxwell, at the British Association in 1873, for example, had been saying:—"But though in the course of ages catastrophies have occurred, and may yet occur, in the heavens, though ancient systems may be dissolved and new systems built out of their ruins, the molecules out of which these systems are built—the foundation stones of the material universe—remain unbroken and unworn". And there was Rutherford changing nitrogen into oxygen according to the reaction:—

$$N^{14} + He^{4} \rightarrow O^{17} + H^{1}$$

Of course it was not at first quite certain, but like all Rutherford's work it was remarkably convincing. If one wants to see how well scientific results can be presented it is worth reading, among many others, some of his papers from the Phil. Mag. of round about 1903-1904 when he was working on the heating and other effects of radium.

What is remarkable for us today is the great simplicity of the means Rutherford employed. It consisted of little more than a brass box which could be exhausted and filled with a gas at a known pressure. In it was mounted a radioactive source of RaC′ α-particles. The α-particles occasionally disintegrated one of the nuclei in the atoms of the gas, in nitrogen, for example, and some of these could pass through a thin mica-window where they made scintillations on impact with a zinc-sulphide screen. The scintillations, little flashes of light, could be seen by a dark-adapted eye, using a low-power microscope, and Rutherford and his assistant Crowe used to disappear into a dark room where, after about five minutes, they could begin to count the scintillations. An hour later they used to come out, blinking in the sun-light, rather like miners coming out of the pit.

The workshop was half-underground and equipped with three antiquated lathes and an old milling machine. They were all jealously guarded by the work-shop steward, Lincoln, and operated by two mechanics. I remember particularly one of them whose name I forget, a kind and amiable little man with pale blue eyes and very thin hair, who spent most of his time reconditioning the small lead accumulators which provided the high-tension supply. For about 30/-d. a week, in intervals between turning or milling, he used to strip-down the accumulators, refill the plates with paste, and reseal the cells with pitch.

But although the technical resources were so meagre, they were sufficient; and they were employed by men who were fascinated by what they were doing. When I recall the atmosphere in the Cavendish in the 20's and 30's I am reminded of some remarks by A. E. Housman in the preface to his book 'Last Poems'. He says:—'It is hardly likely that I shall be revisited by that period of almost continuous excitement under the influence of which I wrote most of the poems in "The Shropshire Lad', nor, he adds, "could I well support it, if it came". I seem to sense there the same intense preoccupation, the same wholehearted devotion to the job in hand, which I suppose is an essential element in any really substantial new contribution, either in the arts or in the sciences; or in any other field of human endeavour.

Can we learn anything about the way in which we can best promote research from the particular situation in Cambridge which produced that brilliant period in the Cavendish. I suppose one should approach such a problem with very great caution. It has always seemed to me extraordinarily difficult to account, for example, for the short triumphant period in classical Greek civilisation; or for Italian Renaissance-painting. The principal figures are themselves unique; and so also is the whole complex of situations and influences which make up the historical social background. But in relation to present problems there are some features about the situation in the Cavendish which are perhaps significant:—Although there were so many brilliant men in the laboratory, they did not commonly work together as a team. No doubt many of them benefited greatly from being members of a laboratory which enjoyed great prestige, and from the stimulus of being associated with a succession of great discoveries. But perhaps more important was their individual mastery of particular techniques and the consciousness of breaking through into a radically new world of experience with resources which were immediately to hand. If one had a new idea it could often be tested with equipment which required only a few weeks, sometimes only a few days, for its preparation. The effort would follow immediately upon the idea, without long and discouraging delays. A painter or a musician enjoys similar advantages.

From what I have said you will see that research in this period of the 20's and 30's might be regarded as a kind of handicraft production. A man alone might have the idea for an experiment, construct the apparatus, make the observations and write the paper, as happened to me, for example, as a research student under C. T. R. Wilson. But already by the late 20's a change was beginning. People in the Cavendish were always keenly on the alert for technical innovations and the increasingly difficult problems arising with the development of the subject called for a growing sophistication in method:—

To demonstrate directly the disintegration of nitrogen in individual collisions of fast α-particles with nitrogen nuclei it was necessary to photograph the tracks in a Wilson Chamber of something like a million α-particles and this led to development by Blackett of the automatic Wilson Chamber. Again, for the accurate analysis of the rare long and short-range particles from radioactive sources, the old methods based on range measurements were quite insufficient and called for large magnets and the increased resolution which they allowed in momentum measurements. This led to the introduction of large permanent or electro-magnets such as those of Rosenblum at Bellevue, or of Cockcroft in the Cavendish. The need to record large numbers of α-particles by methods other than scintillation counting led to the beginnings of electronic methods; and finally the advantages to be gained by producing artificial sources of fast protons, homogeneous pencil beams of great intensity, stimulated the work on the Cockcroft-Walton H. T. generator.

These new innovations owed a good deal to people who had had experience in industry of engineering-scale operations, like Joliot and Cockcroft. There was a remarkable amateurish air about J. J. Thomson's apparatus which was constructed almost entirely in the laboratory; Everett even compounded the wax. But by the early 1930's things were beginning to change rapidly. There was a growing air of professional competence. People began to be less afraid of magnets weighing several tons, and began to take for granted industrially produced vacuum pumps and gauges which operated consistently and without constant attention. But even so, the total budget of the laboratory was very moderate as you may see for yourself if you look up the Cambridge Reporter for any of these years. Even as late as 1929 there were such items as 'salary of Mr. P. M. S. Blackett', £235.10.0d; and 'to Mr. Cockcroft's high-tension apparatus, £57.10.0d'.

It is remarkable to reflect that this was the period in which the scientific and intellectual resources for the great triumphs of the early 30's were being assembled:—For the discovery of the neutron by Chadwick; of artificial radioactivity by Joliot; of the disintegration of light elements by artificially accelerated protons; and the materialisation of γ-rays into pairs of oppositely charged electrons by Blackett and Occhialini. These were the human and technical resources which provided an indispensable foundation for the liberation of energy for nuclear processes in peace and war and the immeasurable consequences which followed.

It was following the brilliant discoveries of the early 1930's and the opening up of an entirely new field of experiment by the development of the Cockcroft-Walton high-tension apparatus, and the discovery by Livingston and Lawrence of the principle of the cyclotron, that the scale and sophistication of experiment in particle physics began rapidly to increase. But even in the late 1940's it was still possible to make important discoveries using relatively simple equipment. Thus both the π and K-mesons and the Λ and Σ hyperons were discovered in experiments with emulsions and Wilson chambers on cosmic radiation; but with the development of the great circular accelerators, the synchro-cyclotrons and the proton-synchrotrons, the field of experiment with cosmic radiation tended to be confined to studies related to the cosmological aspects of the radiation of which I shall speak in my third lecture. It is true that cosmic radiation provides us with a natural source of particles, individuals of which are many millions of times more energetic than any we can hope to generate artificially in the foreseeable future; the energy spectrum of cosmic radiation extends up to at least 10^{21} eV, and the energy of the 'world'-machine, which has been very tentatively considered over the past few years, will according to our present ideas, be designed to produce protons of $\sim 10^{12}$ eV. But the proton-synchrotrons produce directed streams of particles at will, at determined instants in time, and in great intensity; modern proton-synchrotrons produce about 10^{12} protons per sec, homogeneous in energy to better than 0.1%. These great advantages allow us to bring to bear immensely more powerful experimental methods than can be made available at balloon altitudes; and to accumulate results of immensely greater statistical weight even if we could:—

These advantages of the accelerators were of decisive importance. The cosmic-ray studies were successful in discovering nearly all those new particles known to us which have life-times less than $\sim 10^{-9}$ secs; particles, that is which live long enough to give a recognisable track in a photographic emulsion or a Wilson chamber and to suffer a recognisable decay. But of the many hundreds of new particles to which I referred in my first lecture, almost all have life-times so short, $\sim 10^{-20}$ secs or less, that after emerging from the collision between nuclear particles in which they are created, they commonly travel distances less than 10^{-9} cm before decaying; i.e. less than an atomic diameter. It is therefore impossible in principle to record their tracks in a material medium and to establish directly their independent existence. It has to be inferred by showing that the energies and momenta of the secondary products into which they decay, and which can be individually determined have values consistent with their creation by the decay of a parent particle of unique rest-mass.

At this point, an illustration may be helpful. In relativistic mechanics there is a fundamental relation between the total energy E, the momentum p and the rest-mass m_0 of a particle:—$E^2 = p^2c^2 + m_0^2c^4$, where c is the velocity of light. If the total energy E of a particle is known and

its momentum p, the rest-mass m_0 can therefore be determined. Now in many interactions between elementary particles of sufficient Kinetic energy, several π-mesons are created as a result of the collision. Suppose we want to test whether they result from the decay of a very short-lived particle which cannot itself be observed. To be more precise, suppose there is a short-lived particle, W^0, which decays into three π-mesons. Choose then three of the secondary π's resulting from a single interaction and of which the momenta have been determined by deflection, for example, in a magnetic field. Then since we may apply the conservation laws of momentum and energy, the momentum of the supposed parent particle must equal the vector sum, p_w, of the momenta of the three pions, and its total energy, E_w, must equal the sum of values of E for the secondaries. Knowing E_w and p_w, the rest-mass of the particle follows. If we make such determinations of rest-mass for all the possible combinations of three pions from a large sample, plot the distribution of mass-values so determined, and find a well-resolved peak at a particular mass superimposed on a background of values corresponding to combinations in which the individual pions are in fact unrelated to one another, then we may be confident of the existence of the supposed parent. This conclusion may be reinforced if we observe a particle of similar mass and mode of decay in a number of different reactions. An example is shown in fig. 1.

Such methods have proved to be very powerful, but they involved the development of large hydrogen bubble-chambers with magnets weighing hundreds of tons together with other highly sophisticated electronic devices. They and the large statistical weight of the observations are essential to the recognition of these very transient particles, and the experiments can only be mounted at ground level in large institutions. Undoubtedly the same phenomena occur, and many others too, in the very high-energy interactions which can be observed in cosmic radiation, but we cannot bring to bear sufficiently powerful means to make measurements of sufficient weight and precision for their elucidation. Cosmic ray studies have therefore led only to rather general observations on the interactions at these very high-energies which alone will be provided, at least for many years to come, by the cosmic radiation.

By the early 1950's the scale of work with high-energy accelerators, and their great expense in men and resources required for their effective operation had reached the stage where they could be provided only by the most powerful states, and in western Europe it has been found necessary to pool resources in order to do significant work in this field. In 1954 the European Centre for Nuclear Research, CERN, in which twelve states took part was established at Geneva and shortly afterwards work, began on the construction of the 28 GeV proton synchrotron which has now operated successfully for six years.

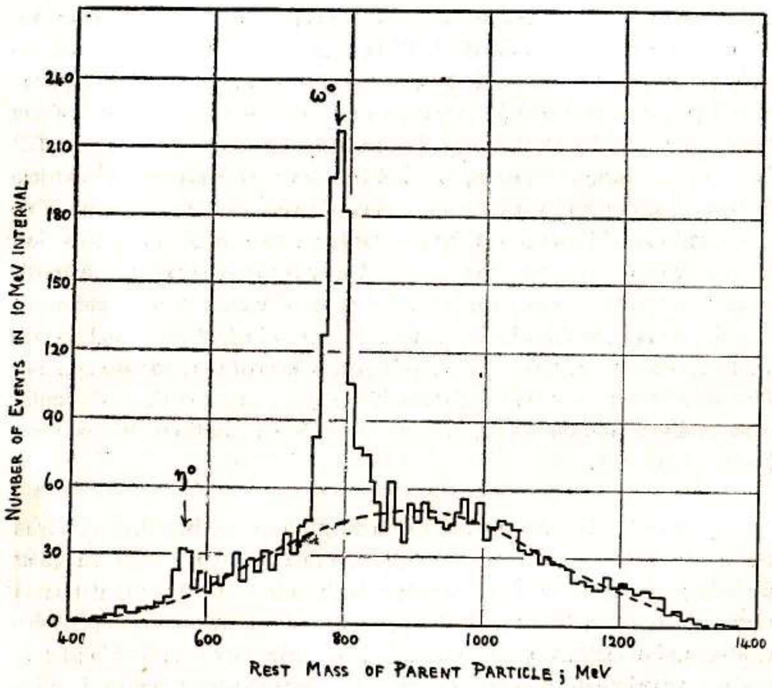


Fig. 1A

These two figures show the results of determinations of the rest-mass of assumed parent particles which decay into three π-mesons, by methods described in outline in the text. If the three π-mesons were always unrelated, the resultant distribution would be of the type shown by the dotted line in A. The two peaks, in both A and B, superposed on the continuous background and marked η° and w°, give clear evidence for two parent particles of mass $\sim$550 MeV and $\sim$780 MeV, respectively.

The results shown in Fig. IA were obtained in experiments on the bombardment of protons by energetic π^+-mesons, the π-mesons being created in the reaction:—$\pi^+ + p \rightarrow \pi^+ + p + \pi^+ + \pi^- + \pi^\circ$. The rest-mass of an assumed parent was calculated for all the possible combinations of $^+ + \pi^- + \pi^\circ$; Since there are two π^+-mesons emerging from each collision, not more than half the possible combinations can appear in the two peaks; and at least half must contribute to the background.

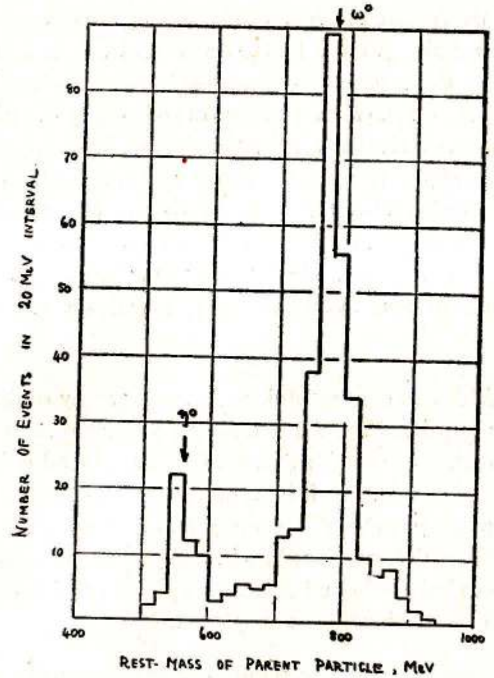


Fig. 1B

In Fig. 1B, the results were obtained in the bombardment of deuterons by energetic π^+-mesons; $\pi^+ + d \rightarrow p + p + \pi^+ + \pi^- + \pi^\circ$. In this case there is only one triplet of π-mesons from each event.

It may be remarked that a large fraction of the events show that the reaction occurs through the creation of one of the mesons η° or w°.

In Fig. 5 of the previous paper these particles are designated of η (o$^-$) and η (1$^-$) respectively.

CERN has been a great success and is now an outstanding laboratory in the forefront of the subject on a world scale. The personnel at CERN, drawn from many countries, now number about 2000 and the laboratory is a noteworthy demonstration of a highly successful international enterprise. I hope later to give you some impression of the scale and quality of the scientific and technical work which is carried out there. It is not merely that enterprises of this nature owe a great deal to technology; in themselves they are an important part of the most advanced technology. They pose all the time, novel problems requiring new technical solutions and by so doing advance technology itself. To name only a few examples, the location of the hundred magnets which determine the nearly circular path of the accelerating protons had to be defined with greater precision than had hitherto been reached by the most modern methods of mensuration; the magnets had to show a degree of uniformity in their magnetic properties, from one to another and in their time variations as the magnetic field surges on every 2 secs, that was far beyond anything previously attempted; the refrigeration and other problems associated with the operation of the hydrogen bubble-chambers were quite unique; and for the analysis of the buble-chamber photographs there is a widespread application of the most advanced computer techniques in radically new ways.

It is astonishing to compare this radically new way of doing science with its high professional standards and its demands on every aspect of planning and management with J. J. Thomson's apparatus in the early 1920's, only 40 years ago. But it is a process which is certainly going to continue in the last years of this century and it is reasonable to expect a similar transformation to take place in many other branches of science as advanced physical methods increase the powers of investigation and the sophistication of the methods employed.

Already in particle physics we are looking towards the next generation of accelerators to serve the experimentalists of the last quarter of this century. The 70 GeV proton-synchrotron at Serpukov is expected to come into operation in about a year; and plans are far advanced for the construction of a 200 GeV P.S. in the U.S.A. In Europe the construction of a 300 GeV P.S. has been under active consideration for more than three years and negotiations on the question will be proceeding during next year. Like the present CERN 28 GeV P.S., such a machine is beyond the resources of the individual states of Europe, and will only be built if sufficient states adhere to a new convention for its construction in an entirely new latoratory. It will cost a total of about £M.150 to build, will consist of a magnet-ring about $1\frac{1}{2}$ miles in diameter, and will be supported, when in full operation, by a total staff of about 4000 scientists and technicians corresponding to a society, with their wives and families, of about 15,000 to 20,000 people.

The advancement of science depends, like everything else, on avoiding a third world war, but given peace and the continuance of our civilisation there seems no doubt that the scale and sophistication of science will continue to grow in the indefinite future. Science is dependent

on peace; but it also contributes to international colaboration and understanding so that a scientist anywhere devoted to the advancement of fundamental science can feel himself a member of a great society of which he is a welcome citizen. At the present time, in the most technically advanced states, about 3 parts in 1000 of the gross national product is spent on the support of fundamental science; in countries which are poorer in a material sense, the proportion is commonly much less.

It is clear at the present time that science is becoming a more and more decisive section of our societies and it is an important problem for modern states to determine what proportion of their resources to allocate to it. There are wide differences of opinion as to how rapidly and to what level the proportion should grow. Some scientists suggest that to aim at about 6 parts in 1000 would be appropriate. Others take the view that in 50 years time perhaps half of our resources will go into it, in a society in which the distinction between science and technology has largely disappeared. What is certain is that support for science and technology, in all states both rich and poor, ought to be increased if it is to play its full part in human advancement.

I ended my first lecture with some remarks of Clerk-Maxwell. Let me end this one by a quotation from the same source.

'There are some minds which can go on contemplating with satisfaction pure quantities presented to the eye by symbols and to the mind in a form which only a mathematician can conceive. There are others who feel more enjoyment in following geometrical forms which they draw on paper, or build up in the empty space before them. Others again are not content unless they can project their whole physical energies into the science which they conjure up. They learn at what rate the planets rush through space, and they experience a delightful feeling of exhilaration. They calculate the forces with which the heavenly bodies pull on one another, and they feel their own muscles straining with the effort.

To such men momentum, energy, mass are not mere abstract expressions of the results of scientific enquiry they are words of power which stir their souls like the memories of childhood.

For the sake of persons of these different types, scientific truth should be presented in different forms, and should be regarded as equally scientific, whether it appears in the robust form and vivid colouring of a physical illustration, or in the tenvity and paleness of a symbolical expression".

We cannot go back to the ways of doing science like those in the Cavendish of 40 years ago, but in the greatly changed conditions of our times we can preserve our delight both in the pleasures of abstract thinking, in making that image or model of the material world which we call theory; and in the great satisfaction to be got from doing things well, in the immense variety of textures, colours and sounds, which make up the material universe.

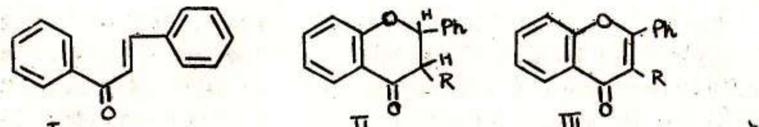
So let me now show a film of the laboratory at CERN which demonstrates that modern science and technology can be not only technically excellent but beautiful and aesthetically pleasing.

ADDRESS TO SECTION E

A NEW GROUP OF POLYPHENOLS OF WOODS—NEOFLAVONOIDS

by

Professor T. R. Seshadri



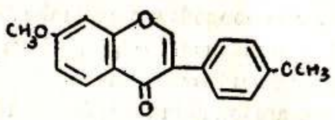
I. Chalkone

II Flavanone, R = H
Flavanonol, R = OH

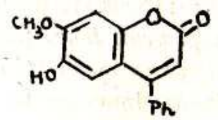
III Flavone, R = H
Flavonol, R = OH

Flavonoids form a large group of naturally occurring organic compounds; they generally contain a number of phenolic hydroxyl groups and therefore constitute important polyphenols. In the past they provided well-known mordant dyestuffs obtained from vegetable sources. This use has disappeared after the advent of synthetic dyes, but their importance has continued because they are components of foods responsible for taste, colouration and antioxidant properties. The skeletons of these compounds contain 15 carbon atoms generally in the form of three rings. The simplest compound, flavone itself is found as a powder on the plants of the *Primula* species. Others are present largely in barks, leaves and flowers in the form of their glycosides. There are several sub-groups in the flavonoids: Chalkones are yellow compounds present in the flowers of *Cosmos sulphureus, Butea frondosa* and many others. Flavanones are closely related compounds; in many cases they accompany the corresponding chalkones. Important members are found in citrus fruits and their glycosides are generally bitter, for example naringin, hesperidin and eriodyctin which are widely distributed. 3-Hydroxy flavanones have been subject of recent study and many of them are widely distributed, for example taxifolin and aromadendrin in woods. But the most widely occurring and important as dyestuffs are flavones and flavonols. The number of compounds in this group exceeds 100. Besides all these, flavylium salts which occur as their glycosides in deeply coloured flowers called anthocyanins also come under flavonoids. Proanthocyanidins have been the subject of very recent study and they are also widely distributed. They derive their name from the fact that when heated with alcoholic hydrochloric acid they form red anthocyanidins. Somewhat similar to them are the catechins which are also common among plants. The general relationship of these groups of compounds is established from the easy conversion of one into another and this interconversion is also very useful for establishing the constitution of new compounds.

The study of flavonoids really began in the second half of the last century and has been steadily growing in volume and in interest. As could be seen from their structures (II, III) the side phenyl is in the 2 position of the chromone system and they constitute derivatives of 2-phenyl chromans. If it happens to be in the 3 position, isoflavones (IV) arise. The earliest member of this group was isolated more than a hundred years ago, but its structure was not understood and unequivocal proof for the existence of isoflavones was provided by Baker and Robinson only in 1925. The number of known isoflavones was small in the thirties of this century. It has increased markedly during the post-war years and their number is now almost 40. Further, there are other isoflavan derivatives with condensed ring structures called rotenoids, coumastans and others which are also numerous and which have marked insecticidal and hormonal properties. It has been considered that isoflavonoids arise from flavonoids by the migration of the side phenyl ring in the course of the biogenetic processes. This has been verified by employing tracer techniques. But the full details are not yet quite clear and have yet to be established.



IV Genistein (isoflavone)



V Dalbergin (neo flavone)

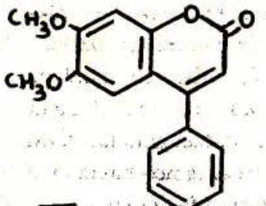
Yet another type of phenyl chromans are possible. They are the 4-phenyl chroman derivatives (V). Their existence was not recognised till quite recently. The earliest members were discovered in the course of the study of the chemical components of heartwoods, an enquiry of fundamental interest for understanding the causes for the special qualities of well known and valuable heartwoods. The properties that we value in good woods are their stability to atmospheric conditions particularly to oxygen and moisture (autoxidation) and their resistence to attack by insects and micro-organisms. The 4-phenyl chromans were first obtained from *Dalbergia* species and were therefore called dalberginoids. More recently, a more general name has been suggested, that is neo-flavonoids. There are three subdivisions: (1) 4-phenyl coumarins (dalbergin group), (2) diphenyl allyl compounds (latifolin group) and (3) condensed type (brazilin group).

4-Phenyl coumarins:

The first few members of the new group to be discovered came under the category of 4-phenyl coumarins. The simplest is dalbergin isolated from the heartwood of *Dalbergia sissoo*, a timber tree very common in North India. It is accompanied by lesser quantities of its methyl ether called methyl dalbergin.

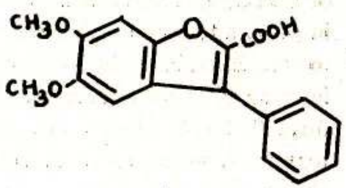
Dalbergin is a hydroxy compound having the molecular formula $C_{16}H_{12}O_4$ with one hydroxyl and one methoxyl groups and lactonic properties. On methylation it yielded methyl dalbergin which could be partially demethylated to dalbergin. The methyl ether was considerably stable towards alkali and gave marked colour with magnesium and hydrochloric acid, emerald green changing to deep red. These were reminiscent of the behaviour of normal flavonoids. But it underwent ready oxidation with neutral permanganate to yield benzoic acid, oxalic acid and 2-hydroxy-4, 5-dimethoxy benzophenone. Further the I.R. spectrum indicated an unsaturated lactone structure. O-Methyl dalbergin was, therefore, considered to be 6, 7-dimethoxy-4-phenyl coumarin (VI) and dalbergin to be 6-hydroxy-7-methoxy-4-phenyl coumarin (V) and these structures were confirmed by synthesis following unambiguous methods. A special feature of methyl dalbergin is that on boiling with aqueous alkali and mercuric oxide it undergoes facile conversion into the corresponding 3-phenyl coumarilic acid (VII) a change involving geometrical inversion followed by ring closure and oxidation.

A group of three compounds have been isolated from the seeds of the tropical plant, *Calophyllum inophyllum:* calophyllolide, inophyllolide and calophyllic acid. Of these, calophyllolide (VIII) is the major component and most important, since it had valuable therapeutic properties. Originally it was considered to be useful against leprosy. More



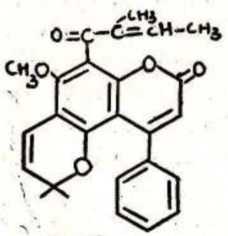
VI

Methyl dalbergin

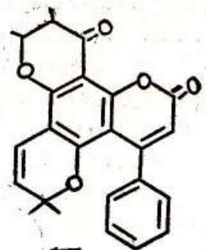


VII

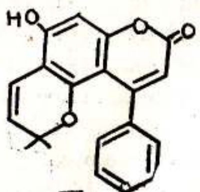
recently it is found to be efficient as a blood anticoagulent. Owing to the presence of two extra isoprene units it has a more complex structure which has been elucidated by the action of alkali and of hydriodic acid and phosphorus on calophyllolide; these reactions yielded a number of products whose constitutions could be established, eventually revealing the correct structure of calophyllolide itself. Demethylation of calophyllolide is accompanied by ring closure and the products are inophyllolide (IX) and calophyllic acid which are inter-convertible. More recently a detailed study has been made at Delhi of the seeds and of the oil for the better utilisation of the components. In this connection the unripe seeds of *Calophyllum inophyllum* were examined in order to detect precursors of calophyllolide. Besides cinnamic acid, a new coumarin, ponnalide (X) was obtained. Its constitution has only one C_5 unit showing that it represents an earlier stage of biosynthesis. Calophyllolide was significantly absent.



VIII



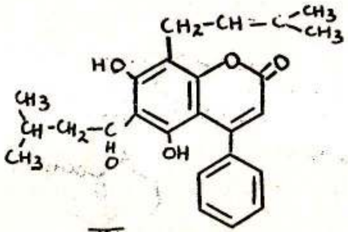
IX



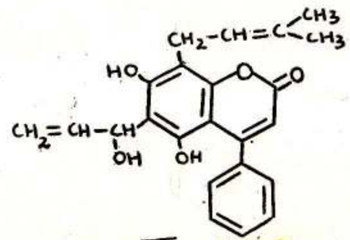
X

From the fruit pulp of *Mammea americana*, an insecticidal plant indigenous to Mexico, a number of components have been obtained; they are closely related 4-phenyl coumarins somewhat similar to calophyllolide. The differences are in the nature of isoprene units in 6 and 8 positions. Of them mammeisin (XI) is the most important. Another

4-phenyl coumarin is mesuol (XII) present in the oil seeds of *Mesua ferrea*, available in Assam. It seems to be an unusual example having an allyl (C_3) unit instead of the isoprene (C_5) unit as nuclear substituent.



XI

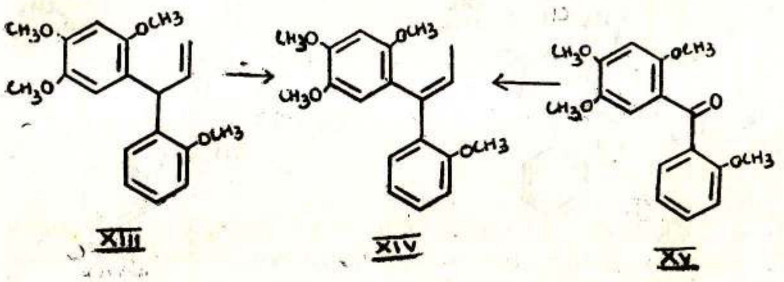


XII

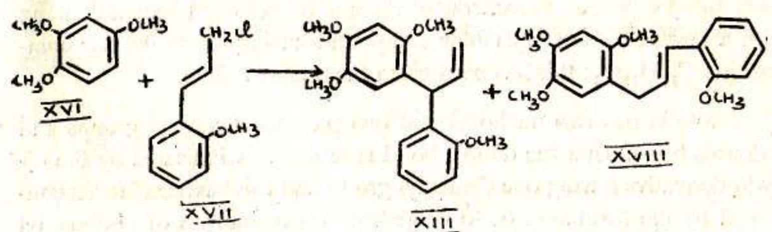
Latifolin Group:

The existence of other types having the same C_{15} skeleton has been discovered by more recent study. This work relates to the chemistry of the heartwood components of *Dalbergia latifolia*, which is a very valuable timber tree found in South India and is commonly called Indian Rosewood or Blackwood. When fresh it is paler in colour but it develops a deep black colour and hardens more and more as it ages. Obviously deep seated chemical changes are involved. Light petroleum extracts from this heartwood considerable amount of coloured material along with a new colourless crystalline compound having the molecular composition $C_{17}H_{18}O_4$; this has been given the name latifolin.

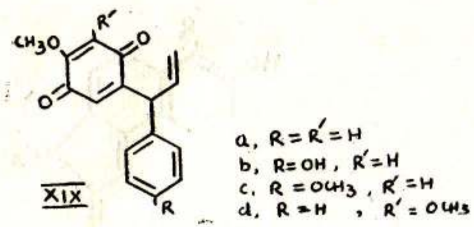
Latifolin has two methoxyl and two phenolic hydroxyl groups and a double bond. That the double bond is terminal is indicated by the dihydroderivative having one C-methyl group and this has been further confirmed by the formation of formaldehyde on ozonolysis of O-dimethyl latifolin. Latifolin and its derivatives are optically active. Neutral permanganate oxidation of O-dimethyl latifolin gave *ortho*-methoxy benzoic acid, whereas latifolin gave salicylic acid. These results indicated that there were two benzene rings each having one phenolic hydroxyl group and these are linked in some form to a C_3-residue. All these properties are accommodated in structure (XIII) for dimethyl latifolin, having the same carbon skeleton as dalbergin which is also found in the wood. This structure was supported by isomerisation of O-dimethyl latifolin with alcoholic potash to give an optically inactive compound (XIV), which could be synthesised using as intermediate 2, 2′, 4, 5-tetramethoxy benezophenone (XV). The I.R. and N.M.R. spectra of O-dimethyl latifolin has further confirmed its structure (XIII). The position of the free hydroxyl groups in latifolin was finally established by ethylation and a parallel study of ethyl ether.

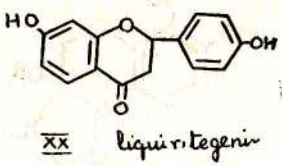


Though the synthesis of isolatifolin dimethyl ether is comparatively easy, the synthesis of the normal compound itself is far more difficult and requires controlled reactions. It has been achieved by using methoxy cinnamyl chloride (XVII) and trimethoxy benezene (XVI) in the presence of $AlCl_3$. A mixture of isomers (XIII and XVIII) is obtained which can be separated by chromatography.



From the acetone extract of the above heartwood besides latifolin and dalbergin, was obtained another yellow crystalline compound which had quinone properties and the molecular composition $C_{16}H_{14}O_3$ with one methoxyl. The location of this methoxyl in the quinone part was clear when the compound on oxidation with alkaline permanganate yielded benzoic acid. It has therefore the structural formula (XIXa) and has been named dalbergenone since it is closely related to dalbergin, is an ethylene and a quinone. This structure is in agreement with its spectra and has been confirmed by synthesis.





Examination of the components of the heartwood of *Dalbergia nigra* has led to the isolation of dalbergenone along with its 4′-hydroxy (XIXb) and 4′-methoxy (XIXc) derivatives.

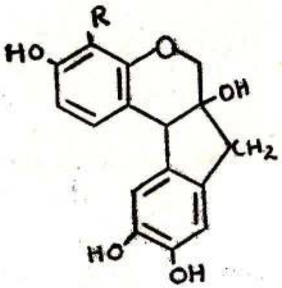
As a small fraction of the extractives of *D. latifolia* which is soluble in aqueous sodium carbonate was isolated a flavonoid called liquiritigenin (XX), its occurrence along with neoflavonoids may be significant for biogenesis. Also intriguing is the association of the above with simple aromatic ketones like 2, 4, 6-trimethoxy acetophenone and 2, 5-dihydroxy-3,4-dimethoxy benzophenone.

Brazilin group:

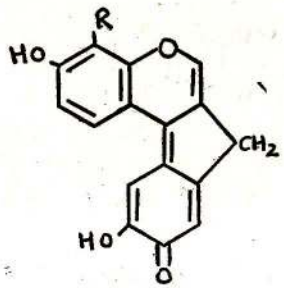
Here it may be mentioned that the earliest neoflavonoids to be discovered were really brazilin (XXIa) and haematoxylin (XXI b) and these were known in crystalline condition even a hundred years ago. They were the main components of the well known dyewoods, brazil wood and log wood respectively indigenous to South America. Brazilin is also present in the important South Indian dyewood, sappan wood. Their constitutions were established during the first quarter of this century, largely by the work of Perkin and Robinson and their collaborators. They are almost colourless, astringent and antibiotic. They undergo oxidation readily into deeply coloured quinonoid compounds called brazilein (XXIIa) and haematoxylein (XXIIb), which are the real dyestuffs. Originally they were considered to be derived from normal flavonoids, but now they are recognised to be neoflavonoids.

Biogenesis:

Since neoflavonoids now constitute a large number and have some variations, the study of their biogenesis becomes important. It is now well established that normal flavonoids consist of C_6 (phloroglucinol or resorcinol) and C_9 (cinnamic acid) units. The former is derived from acetate and the latter from shikimic acid. The two parts are linked through



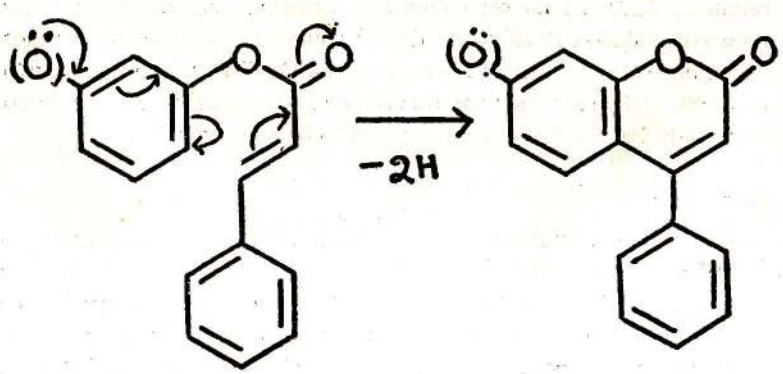
XXI a, R=H
b R=OH



XXII a) R=H
b, R=OH

the end carbon atom (γ) of the C_9 unit. In neoflavonoids the two parts are the same, but they are linked through the α-carbon atom. There are two ways in which details can arise: one is that the coumarin compounds are first formed and they undergo reduction and other changes to yield the allyl compounds of the latifolin type and the second is the reverse procedure. The first seems to be the correct one.

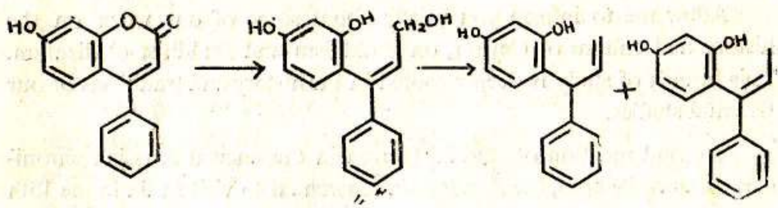
If the C_9 unit is represented by benzoylacetic ester, it reacts readily with resorcinol or phloroglucinol to yield 4-phenyl coumarins and the reaction is the well known Pechman's condensation. If the C_9 is cinnamic acid the first product will be dihydrocoumarin and a further stage of oxidation is involved. It can happen in an alternative way with oxidative coupling as represented in the formulae.



Thus we consider that the same cinnamoyl coenzyme A which gives rise to the large and important branch of flavonoids by a C-acylation sequence also gives rise, by an O-acylation sequence to the neoflavanoids. There is support for this idea from the significant observation already mentioned that a flavanone, liquiritigenin, occurs with the neoflavanoids in *D. latifolia*.

Besides liquiritigenin, other C-acylation products like benzophenone and acetophenone derivatives also occur. In this connection one interesting observation was made in our laboratory that latifolin type of compounds react readily with electrophillic groups like nitro, acetyl, benzoyl and cinnamoyl displacing the allyl group. This may also be a natural process explaining the co-occurrence of these minor products along with the neoflavonoids.

From the 4-phenyl coumarins to latifolin type requires 2 stages of reduction and they have been carried out in the laboratory using model reactions. The first stage uses $LiAlH_4$ yielding the corresponding cinnamyl alcohol which is stabilised by methylation of the phenolic hydroxyl and the second stage needs further an acid catalyst, $AlCl_3$ or $ZnCl_2$ which brings about isomeric changes also. Though in the laboratory, a mixture of products is obtained, in nature the reaction seems to be selective leading to allyl compounds only.



The quinones like dalbergenones are products of oxidation of the latifolin group. The biosynthesis of brazilin and haematoxylin is an intriguing problem. More experiments will have to be done, but there is no doubt that the appropriate 4-phenyl coumarin is the intermediate stage.

ADDRESS TO SECTION F

STUDY OF CEYLON IN THE SOVIET UNION

by

Professor VLADIMIR BALABUSHERICH

(Paper presented at the 22-nd Annual Session of the Ceylon Association for the Advancement of Science)

Soviet people take a keen interest in the history and culture of the peoples of the East. They also want to know as much as possible about the way of life of the peoples of Ceylon, their history and remarkable culture. Quite a lot of books on Ceylon, on its past and present, including fiction by Ceylonese writers are published in the USSR. Soviet Orientalists who study the historical and cultural development of the peoples of the East, perform an honourable task. They deeply respect the ancient and great culture of Ceylon and are well aware of the considerable contribution made by Ceylon to the treasury of world civilization and of the important role played by Ceylon in the struggle of the peoples of the world for peace, freedom and progress.

Allow me to inform you briefly about some of our work on the history and culture of Ceylon, on Buddhism and Buddhist civilization. This branch of study is deeply rooted in the history and traditions of our Oriental studies.

We find mention of Buddhists even in the ancient Russian chronicles. Afanasy Nikitin, the first Russian merchant to visit India in the 15th century, wrote about Buddha's believers in his diary.

Interesting material may be found in Russian documents of the 17th and 18th centuries. In the late 17th century Buddhism had made its way into the Eastern regions of Russia, into Buryatia, and became the main religion of the population there.

Gradually the interest in the study of Buddhism and the Buddhist civilization grew. Museums of St-Petersburgh (now Leningrad) started getting valuable specimens of the material and spiritual culture of the

Buddhist nations of Asia and among them ancient manuscripts. Russian scholars travelled to the East to study Buddhism and Buddhist civilization bringing back valuable manuscripts of Buddhist texts. Especially prominent among the students of Buddhism in the 19th century was Prof. Ivan Minayev, founder of the Russian Indological and Buddhological schools. Prof. Minayev's scholarly interests were focussed on the study of Buddhism and Buddhist civilization. In order to get better acquainted with the living practices of Buddhism, and to penetrate into the world of Buddhist civilization, Minayev went to India, Burma and Ceylon. In Ceylon he studied the major Pali texts, paid visits to the leading cultural centres, where, as he put it, he read "the living story of the life of mind and soul of the ancient people".

Minayev attached great significance to the study of Buddhism believing it important "for every modern intellectual". He himself was an outstanding scholar of Buddhism and of Buddhist Pali and Sanskrit texts. To him goes the credit for publishing and translating into the Russian language one of the most important canonical Pali works of Patimokha. Among the manuscripts used by Minayev for this purpose was also a manuscript from Ceylon written in Singhalese script. This manuscript is now in the manuscript collection of the Leningrad branch of the Institute of Asia of the USSR Academy of Sciences.

Minayev is well-known in world Buddhology for his publications of such important works as the Kathavathupakarana, Bodhicaryavatary, and others.

A number of Pali Buddhist works discovered by Minayev during his travels in Ceylon and Burma were published by him in the Journal of the Pali Text Society. Among them were the Petavatthu, Anagátavamsa, Sandséakatha, Sima-vivádavinicchàyakatha, etc.

Minayev was quite well versed in Pali language. While in Ceylon he debated in Pali on various problems of the Buddhist doctrine. From under his pen came the famous grammar of the Pali language later translated into English and French. I am happy to note that this grammar is well known in Ceylon as well. Is it not a graphic example of distances being no obstacle to true science!

The glorious traditions of the study of Buddhism and Buddhist civilization were carried further by Minayev's pupils—the well-known Buddhologists Academicians Oldenburg and Sthcherbatsky. The range of Oldenburg's scholarly interests was very wide. He studied Buddhist literature and art. Buddhist manuscripts and archeological finds. Oldenburg's works on the Dhammapada are well-known: he was the first to find and study the Prakrit version of this most important Buddhist text.

Recently Soviet Orientalists marked the centenary of the outstanding Soviet Buddhologist E. I. Sthcherbatsky who was one of the first to initiate the study of Buddhist logic. His works are well-known in the Buddhist countries. Oldenburg and Sthcherbatsky founded the world famous Bibliotheca Buddhica where many prominent scholars of the world published their contributions. A number of important Buddhist texts were printed in the Bibliotheca Buddhica. At present the publication of the series continues in the USSR. Recently the Russian translation of the Dhammapada was published in it.

Soviet Buddhologists strive to promote in all ways the traditions of the Russian school of Buddhist studies which won recognition in the world. In recent years alone our Buddhologists published, beside the Dhammapada, the Russian translations of Jatakamala, of a number of Avavanas, and are preparing now the translation of the Sutta-nipata and Milinda-panha, and the scholars on Ceylon are soon going to finish the translation of the famous Pali chronicle of Ceylon—the Mahavamsa.

Our Buddhological studies, including works on the history and culture of Ceylon, are based on original sources among which are the rich manuscript collections of Soviet libraries.

I am happy to tell you that in recent times Soviet scholars registered considerable progress in the study of Buddhist civilization and brought to light new and interesting data on the monuments of that civilization in Central Asia. Such monuments have been found in various regions of Central Asia pointing to the great role played by Buddhism there in the first millenium A.D.

Soviet archaeologists discovered several Buddhist monasteries of the Kushan and post-Kushan periods, remnants of Buddhist sculpture, inscriptions, and even fragments of ancient Buddhist manuscripts on birch bark and palm leaves.

The Buddhist manuscripts thus found are of a special scientific interest. For example, a recently discovered palm leaf manuscript dated back approximately to the 7th century A.D. and is one of the most

ancient of the known Buddhist works on palm leaves. Preliminary analysis suggests that it is a part of the Buddhist canon Pratimoksha compiled by the representatives of the School of Sarvastivada.

I would like also to mention another recent find which might be of interest to my Ceylonese colleagues. A few years ago a big Buddhist monastery with monks' premises, stupas and ritual sculpture was excavated in Tajikistan, in the vicinity of Dushanbe, on the Ajina-tepe hill. This year archaeologists excavated a gigantic statue of a lying Buddha, very much like the famous lying Buddha of Gal Vihara in Polannaruva. What might be the explanation of this unity of tradition in countries so far away from each other and considered regions of Southern and Northern Buddhism? Perhaps, the study of these facts would yield the answer to more general problems of Buddhism and Buddhist civilization, too.

At present Soviet scholars are trying to solve these problems and it goes without saying that their Ceylonese colleagues will say their competent word on them.

The ranks of those who study the problems of Buddhism in the USSR expand as young scholars join them. I would like to mention here the name of one of them because you know him. He is Dr. Bongard-Levin who recently spent in Ceylon nine months studying the history of Buddhism, Buddhist civilization and ancient Pali texts. He published in the Ceylonese press a number of articles on the study of Buddhism in the USSR and on the newly discovered monuments of Buddhist civilization and read papers at the Asiatic Society of Ceylon and the Peradeniya University. His stay in Ceylon was extremely useful, and I take this opportunity to express our gratitude to Ceylonese scholars for the assistance and hospitality accorded to him.

A comprehensive approach, study of all aspects of economy, history and culture, are characteristic of our works on Ceylon as well as of the entire Soviet Oriental Studies.

At present our effort is directed at writing fundamental works—monographs on the major problems of Ceylon, its past and present.

Our scholars on Ceylon are working now on the history of Ceylon from the ancient times up to the present day. The work will be based on all available source materials at the disposal of Soviet Scholars. It will be a comprehensive study covering the entire process of Ceylon's historical evolution, the first to be published in the USSR. The main features of the historical evolution of Ceylon will be traced on the basis of an analytical study of existing materials and literature, and the various stages of the struggle of the Ceylonese people for independence and the social, economic and cultural progress of their country will also be shown. We shall strive to make our work not a story of the deeds of kings and emperors, but an objective history of the people, their culture, aspirations, fight for freedom and happiness of their land. The authors of the work are guided by the fundamental premise that it is the people who create history.

You must realise that writing a history of Ceylon is a very complicated and time consuming job. Many important problems of the country's history and culture still remain to be solved. We know perfectly well that the leading role in the study of Ceylon's history and culture belongs to you, scholars of Ceylon. And we hope to receive assistance and friendly advice from our Ceylonese colleagues who are held in high esteem by Orientalists all over the world.

Speaking on our works on Ceylon already published or prepared for publication, I would like to dwell only on two recently completed monographs dealing with the ancient and modern history of your country.

Dr. E. S. Semeka devoted several years to the study of the socio-economic and political role of the Buddhist sangha in the ancient and medieval states of Ceylon and defended a thesis on that subject. She used as source material documents printed in Ceylonese publications and materials available in Soviet libraries. She also made use of ancient inscriptions in the "elu" language and of Pali and Sanskrit texts. As far as we know, valuable researches on this subject are conducted by Ceylonese scholars and, in particular, by young teachers of the Peradeniya University.

Another work on the history of Ceylon, "Studies in the Contemporary History of Ceylon" covering the period from the late 19th century up to 1956, was written by Dr. E. Talmud. The author gives an analysis of the social and economic changes which took place in Ceylon during that period and outlines the most important stages of the liberation struggle of the people of Ceylon, their attainment of independence and the first achievements in the building up of their sovereign state.

Some of our young scholars study the economic problems of contemporary Ceylon.

The Institute of Asia of the USSR Academy of Sciences is a leading Soviet research centre where the study of Ceylon as well as of other countries of the East is carried on. And it is its research workers who are authors of the majority of the works mentioned by me. But history and culture of Ceylon are also studied at various Soviet Universities. Students of the Moscow University, for instance, who want to specialize in Ceylonese, studies, learn Singhalese and Pali, study history of Ceylon, the history of Ceylon's culture and of Buddhism.

Quite popular are in the Soviet Union books by Ceylonese writers. Especially well-known are the translations of novels, and short stories of the renowned Ceylonese writer Martin Wikramasinghe. Last year his three best known novels—Changing Village, The Last Age and The End of the Century—were translated directly from Singhalese. Martin Wikramasinghe's story Modul Duva is also very popular with the reading public.

Stories by other contemporary Singhalese and Tamil authors also appeared in Russian. A collection of short stories by writers of Ceylon includes works by Gunadasa Amarasekera, G. B. Senanayake, K. M. Sirisena and by Tamil writers V. A. Irajarattinama, K. Daniel, and others. All these works, as well as stories by Ceylonese writers appearing in Soviet magazines help the Soviet people to get a better insight into the life of the freedom-loving people of Ceylon.

But, of course, what we have done in studying history, culture and economy of Ceylon is far from sufficient. We shall strive hard to publish more books on Ceylon. Soviet scholars will try to help the Soviet readers to get a better knowledge of the country with which the Soviet Union maintains friendly relations.

The scholars of the Soviet Union and Ceylon share many common scientific interests. Certain problems of Buddhism, of the history of culture, etc. can be tackled through our joint efforts. It is gratifying to know that our scientific contacts are growing stronger, Soviet scholars were happy to welcome their colleague from Ceylon—Prof. G. Mendis, President of the Ceylon Branch of the Royal Asiatic Society, at the 25th International Orientalists' Congress in Moscow. For a number of years the well-known scholar Prof. Malalasekara delivered stimulating lectures on Buddhism and Pali at the Moscow University and the Institute of Asia. He made not a small contribution to the fostering of our scientific contacts. Recently our young research scholars E. Talmud and L. Ivanow studied at the Peradeniya University.

I am convinced that our contacts will continue to develop in the future. They will serve a very important and noble cause—the promotion of mutual understanding and better cultural relations between our peoples for the benefit of our two countries and world peace.

Some people may say that geographically Ceylon is very far away from the USSR. In our days distances do not matter, especially between friends, among those who want to see each other, who wish each other peace, happiness and prosperity.

POPULAR LECTURE

THE SHAPES OF TREES

by

Professor A. R. Clapham

When, during the war, I was a member of the Home Guard, I was introduced to a classification of trees based on features of their general shape. This was a less elaborate and less generally serviceable classification than any used by botanists, but it meets my present purpose admirably. There were only three classes of trees: fir-trees, bushy-top trees and poplars. If the classification had been devised in Ceylon there would quite certainly have been a fourth class: palm-trees, unbranched and with a terminal rosette of large leaves, as in most palms but as also in some few other trees including the papaw, *Carica papaya*. There are no native palms in Britain. What are termed palms to attract visitors to our south-coast resorts are in fact not palms at all, and even they are non-native introductions.

A. Fir-trees

Let us begin by considering the mode of growth and consequent shape of the above-ground part of a 'fir-tree'. The most striking feature from our present standpoint is the vertical main stem or 'leader' which in the great majority of conifers (all termed fir-trees by the British non-botanist) continues to grow vertically upwards throughout the greater part of the life of the tree. In contrast with the leader are the relatively short and more or less horizontally spreading lateral branches. What determines this clear-cut distinction between leader and laterals, which is responsible for the characteristic appearance of a fir-tree?

Over a long period from the middle of last century the following relevant facts have been established:

1. The leader is radially symmetrical and behaves like any negatively geotropic shoot. Thus:

(*a*) if displaced from the vertical it curves upwards and resumes its former direction of growth;

(*b*) if rotated on a horizontal klinostat it does not curve upwards;

(*c*) if decapitated and then displaced from the vertical it does not curve upwards, but

(*d*) if, after decapitation, the tip is replaced by agar or lanoline containing heteroauxin (indole-acetic acid), then it does curve up-wards.

We infer that the normal mode of growth of the leader is related to the production by its apex of IAA (indole-acetic acid) which is transported downwards and promotes elongation at an even rate all over the cross-section. Any displacement from the vertical results in a lateral transport of IAA close to the tip and a consequent unequal distribution over the cross-section in the elongating zone, so that a curvature results which corrects the orientation.

The lateral shoots are commonly more or less dorsiventral, the leaves being so held that it is easy to distinguish between the top and bottom sides of the shoot. If they are displaced from their near-horizontal or obliquely ascending orientation at a time in the spring when they are elongating actively, the new growth soon bends upwards or downwards until the former direction of growth is resumed. There is, in other words, a mechanism whose effect is to bring the shoot back to its normal orientation after displacement, just as is true of the leader; but the normal orientation is at some angle between vertical and horizontal. Such organs are termed 'plagiotropic', and we now have to consider what differences between leader and laterals cause the former to be in a rest-position when growing vertically upwards but the latter when growing plagiotropically, and confer the capacity of both to return to these different rest-positions when displaced from them. Let us examine the evidence from further experiments.

If the unilateral effect of gravity is eliminated, as by holding vertically upwards or vertically downwards or rotating it on a horizontal klinostat, a lateral shoot in the stage of active growth curves so that its former upper side becomes convex: it acquires a *dorsoconvex curvature*. The leaves of many shoots have long been known to behave in a similar way.

This dorsoconvex curvature seems at first sight to be independent of orientation in relation to gravity. But, although there is no *current* unilateral gravitational stimulus, the direction of the curvature and the whole of the morphological dorsiventrality are determined by orientation in relation to gravity at an earlier stage. For if a shoot is held in an inverted position from before bud-break, then the new growth shows an inverted symmetry: its new upper side, which is really the lower side in strictly formal terms, assumes all the morphological appearance of an upper side, subsequent curvatures developing when there is no current gravitational stimulus are then such that this new upper side becomes convex. This means that the lateral shoots must have a positive geotropism of a special kind: one that is induced in the breaking bud and then persists, irrespective of the current direction of the gravitation stimulus.

This cannot be the whole story. A positive geotropism of this kind would result in lateral shoots growing in spirals unless there were some other factor at work. The outcome of other experiments throws some light on the situation. If an actively growing lateral shoots of a fir-tree is placed horizontally but upside down it curves *upwards* so strongly that it often coils into a complete circle. If placed horizontally on a flank it curves *obliquely upwards*. Finally, if a lateral shoot whose bud has not yet broken is rotated on a horizontal klinostat until growth begins and is then held horizontally at rest, it curves *upwards*, whatever its current orientation in relation to the original top and bottom sides.

The inference from these observations must be that the lateral shoots of fir-trees are negatively geotropic, like the leader. For the inverted shoot will now have both the special positive geotropism and the normal negative geogropism acting in the same sense, both tending to make the shoot curve upwards, whence the very powerful curvatures. The lateral placed on its flank will curve in the direction of the resultant of two curvature-tendencies, one in the horizontal plane (the special positive geotropism) and one vertically upwards (the normal negative geotropism). And rotation on the klinostat before bud-break will have prevented the establishment of the special positive geotropism and on stopping the klinostat the shoot will curve upwards under the influence of a normal negative geotropism in relation to the current gravitational stimulus.

The plagiotropic rest-position would appear, then, to reflect a balance between two opposing curvature-tendencies: the early-induced and persistent positive getropism, independent of the current gravitational stimulus; and the normal negative geotropism, non-persistent but reacting to the current gravitational simulus. The latter will have a strength which varies with the angle of orientation. It has been shown that it is more or less proportional to the sine of the angle made with the vertical, so that it is maximal in the horizontal position and zero in the vertical. If, as may be supposed, the special positive geotropism is constant in strength, irrespective of angle of orientation, then the reason for a characteristic rest-position, somewhere between horizontal and vertical, becomes clear.

Two questions arise at this stage: how can two opposing curvature-tendencies co-exist in one and the same plant-organ, and why does the lateral shoot behave differently from the leader?

(*a*) We are now fairly clear that an essential stage in geotropic responses is the unequal distribution over the cross-section of the plant-organ, as a consequence of a unilateral gravitational stimulus, of substances that control the rates of growth of the cells of the organ. There is an accumulation of certain growth-regulators on the lower or upper side of the organ, or, perhaps, of growth-accelerators on one side and of growth-inhibitors on the other. We know little yet about either the mechanism of the unequal distribution of these substances or the way in which they control the rate of elongation. There is some evidence that they bring about physical changes in the cell-wall, but this may be a very indirect effect. There is some evidence, too, of structural effects of a unilateral gravitational stimulus, and these may play a part in the differential growth of the top and bottom sides of a plant-organ. There is in any case no insuperable difficulty in understanding how two different curvature-tendencies may coexist in the organ.

(*b*) But why does the main shoot or leader behave differently in these respects from the side-shoots or laterals?

(i) It has long been known that if a fir-tree loses its leader, whether by accident or by human design, one of the branches of the top set will curve upwards to replace it. The same result follows the ringing of the leader down to the xylem at a point below the apical bud. In an experiment reported by Munch all the laterals within a length of one and a half metres below the point of ringing responded by detectable

upward bends, and the bending involved a good deal more than the actual elongating zone of the current year's growth: upward curvatures occurred in regions where secondary thickening had been proceeding for one or more years. It can be shown that this is a consequence of the formation of longer tracheids and other secondary elements on the lower side than on the upper, so that the shoot is forced into an upward curve. Many herbaceous perennials behave in similar manner: on decapitating the main shoot, plagiotropic laterals curve upwards and become negatively geotropic. In both woody plants and herbs it has been shown that replacement of the removed apex by a blob of gelatine or lanoline containing IAA prevents this erection of laterals. We see, then, that a factor essential for the downward (geopositive) curvature-tendency, the one that opposes negative geotropism in lateral shoots, is controlled by the growing apex of the main shoot, and that IAA can replace this main apex in providing the control. It does not follow, of course, either that it is in fact IAA itself that determines the direction of growth in such experiments, or that IAA is involved at all in the intact plant, but the results of such experiments do give us a lead in our further thinking and experimentation. And they do make the point that control by the apex of the main shoot or leader is an important factor in determining the plagiotropic growth of laterals.

It is a point of some interest that commercial fruit-growers in America have brought about a widening of the angle of branching in young fruit-trees by removing the apical bud and apply IAA-paste to the cut end. The angle has been widened from 48° to 65° in this way, a beneficial result because branches are found to be better able to bear a heavy load of fruit if they are held at a wide crotch-angle.

A further point of great interest is that if we watch a decapitated or ringed fir-tree for some time, we find that one of the erected laterals, usually the strongest in the top set, attains dominance, henceforward remaining erect while all the others begin to bend back again towards the original rest-angle. The old tyrant has been replaced by a new one!

Our study of fir-trees has therefore led us to the conclusion that the characteristic more or less horizontal growth of lateral shoots is a consequence of the *tyranny of the main apex*, initially exercised by the transmission down the main shoot of some growth-regulating substance which in some way imposes a dorso-convex curvature-tendency upon the lateral shoots in relation to the side that was uppermost at the time of bud-break in the terminal bud of the lateral shoot. The terminal bud of the lateral shoot itself supplied the growth-regulator that confers a negative geotropism or dorso-concave curvature-tendency on the shoot, so that growth-regulators are being supplied to the elongating zone from two sources: main apex and own apex. The resulting direction of growth is a consequence of the joint effect of these two supplied of growth-regulators.

(ii) We have so far left unanswered the question 'Why should the main apex exert an influence on lateral shoots different from that exerted by the apices of laterals on the main shoot? What is the essence of 'mainness' in this connection?

I think it can first be said that the difference is almost certainly one of degree, not of kind: a quantitative, not a qualitative, difference. It may further be asserted that in recent years more light has been thrown on the topic of apical dominance by studying the *amount* of growth rather than the *direction* of growth. Experiments bearing on this question were carried out by Professor Wareing and his collaborators in Aberystwyth some ten years ago. Following a hint in the horicultural literature they studied the extension-growth of branches of Japanese larch (*Larix kaempferi* (Lamb.) Carrière), a kind of fir-tree. They showed that the branches grew more in length the more vertically they were held. Branches allowed to maintain their normal obliquely upward direction of growth extended on the average by 29.5 cm., those fixed in a horizontal position grew 17.5 cm. and those held vertically downwards grew only 14 cm. in the same growing season. They carried out a number of further experiments with bushy-top trees, chiefly with young potted plants of apple, cherry, plum and black currant. Young apple plants, for example, were pruned back to a height of 24 inches and the subsequent growth restricted to laterals from the top two or three buds. Some of these laterals were held vertically, some horizontally. When all were held vertically or all horizontally the uppermost lateral grew most and the lowermost least. When only two laterals were retained, those trained vertically grew most, even when they were the lower members of pairs, the upper being trained horizontally. In other words, vertical shoots grow more vigorously than horizontal shoots; and of two lateral shoots borne at different levels on the main stem, and both growing vertically, the one nearer to the apex of the main stem grows the more vigorously, other things being equal. To this we must add that if two lateral shoots, borne

at the same level on the main stem and growing at the same angle to the vertical, are made to differ in vigour, as by darkening one of them for a time, then the weakened lateral is rapidly inhibited in its growth by the stronger. If the stronger shoot is removed, the weaker will grow more rapidly again; and if the stronger shoot is removed and then replaced by gelatine or lanoline containing IAA, the inhibition of growth of the weakened shoot persists. From all this we can infer that the apex of the main shoot or leader is able by virtue of its position and its vertical direction of growth to exert dominance over lateral shoots on the same stem, this dominance being manifested as a reduced extension-growth and also, commonly, a dorso-convex curvature-tendency in the lateral shoots. There is no difference in kind between the main apex and the apices of lateral shoots: dominance arises in the first place by virtue of position and direction of growth, and is maintained and increased by the greater flow of growth-regulators from the main apex to the lateral shoots than in the reverse direction, this in turn arising from the greater vigour of growth of the main apex and shoot. This explains why one of the laterals is able to replace the main apex after decapitation or severe injury, and why the successful one amongst many laterals can exert dominance over the others.

Despite the considerable amount of information on this topic that has been gained in recent years we are still very much in the dark as to the mechanism of action of the growth-regulators that seem responsible for apical dominance. They appear to determine in some way the extent to which the dominant shoot can act competitively as a sink for nutrient materials, and this might explain correlative inhibition of growth. But it does not explain the imposition of a dorso-convex curvature-tendency, unless in a very indirect way.

B. Bushy-top trees

It is characteristic of bushy-top trees that they have in general a much less clear-cut distinction between a main shoot or leader and lateral shoots, at least after early stages of growth. But when young their behaviour is much the same as in fir-trees. The plagiotropic growth of their laterals is here too the consequence of a balance between opposing curvature-tendencies. Some behave very like fir-trees, the downward curvature-tendency being induced at bud-break and then persisting throughout the whole period of elongation, even on a horizontal klinostat. This is particularly true of those with morphologically dorsiventral lateral shoots, like beech, lime and hazel. Others develop a much less persistent geopositive curvature-tendency, lost after a few days or even a few hours on the horizontal klinostat. Not only is it less persistent; it is also less strong, so that lateral shoots ascend at a fairly high angle with the horizontal. They may often be bent downwards under their own weight when their leaves unfold, but it is noticeable then that they sag in a downward arc behind the still ascending tip. Such trees include alder, ash, birch, horse-chestnut, mountain-ash, oak and sycamore—all trees with radially symmetrical lateral shoots. If one of these laterals is held firmly for a day or two in a horizontal position, but rotated through an angle from the normal orientation, and then is placed in a position in which it has no gravitational stimulus, it now curves so that the side uppermost while it was being held becomes the convex side of the curve. This suggests a much more readily induced and readily lost positive geotropism or dorso-convex curvature-tendency than in fir-trees, and so a smaller difference between the two coexisting curvature-tendencies in these shoots. The distinction between leader and lateral is less clear, too, than in fir-trees. Control by the apex of the leader seems much less tight than in fir-trees and is lost at a comparatively early stage, several large branches tending to rise at much the same angle and others at various angles. Here a persistent tyranny is replaced by a kind of oligarchy or cabinet government. With less inhibition of extension-growth than in fir-trees, lateral branches seem able to gain at least a partial independence of the main apex and then grow more and more nearly vertically upwards, this in its turn causing them to become co-leaders with the original main stem. A further point is that the original main stem may lose its apical bud at a fairly stage, so that the leader is necessarily replaced by one or more 'ersatz-leaders'.

Bushy-top trees may be used as convenient examples of the role of two other factors that play an important part in determining the shapes of trees.

If we suppose that the main shoot of a seedling tree gives rise to two laterals in the second season, that each of these three shoots gives rise to two branches in the third season, and so on, it is not difficult to see that every shoot present in a given season is replaced by three in the following season, so that when the tree is n years old it will have 3_{n-1} shoots in all.

The German forester-botanist Wiesner made some actual counts of shoots on trees of various species at various ages. For beech he found the following discrepancies between fact and theory:

Age of tree	*Observed numbers*	*Expected numbers*
2 years	—	3
3	8	9
4	20	27
5	43	81
6	66	243
10 years	295	19,683
For shaded birch the 10-year number was	182	
non-shaded	238	

Possible explanations for the discrepancies between what seem modest expectations and the observed facts are:

(*a*) that fewer buds grow out than even the postulated two per shoot;

(*b*) that shoots die and are shed after a few years.

Both these suggestions are found to be true. Let us first consider the failure of buds to grow out.

Every year's growth bears several buds, some in the axils of bud-scales, some of foliage-leaves. It never happens that all these buds grow out. In early stages some of the buds at the distal end of last year's growth grow out into strong laterals. Others lower down may form weaker shoots or specialized short-shoots. As the tree becomes older the number growing out becomes progressively smaller, and often only the terminal bud breaks its winter dormancy. Various factors, including desiccation by drying winds and salt-spray, insect attack, etc., may play their part in this, but the chief reason for the persistent dormancy of the majority of the buds is that they are prevented from growing out by the actively growing terminal buds and the one or two laterals above them that do grow out. This is another way in which the main apices dominate laterals, in this case *by imposing a persistent* dormancy upon them, just as they impose plagiotropism on those laterals that do grow out. And the mechanism of this *second form of tyranny* is similar in kind to that of the first; it is possible to remove the inhibition by decapitating the main shoot (and growing laterals), and it is possible to restore the inhibition by replacing the main apex by heteroauxim paste. It is also possible, at least in some trees, to remove the inhibition by bending the main shoot into an arc, or by supplying kinetin to the inhibited buds.

Again the precise mechanism of this inhibition is unclear, though it does seem due to a substance, and probably an auxin, which travels down from the main apex and then, directly or indirectly, prevents the lateral bud from growing out. This actual inhibition has usually been thought to be a specific hormonal effect of some kind, but some have thought it the result of the diversion of food substances from the lateral by the strong-growing apex. Probably both factors operate, for it looks likely that the direct effect of the auxin may be on the differentiation of a vascular supply to the lateral bud from the xylem and phloem of the main stem. If no adequate channels for translocation are formed, there will be no adequate supply of translocates to the lateral bud. Against this simple view is the fact that the strength of the inhibition seems directly related to the amount of labelled carbon from labelled auxin that reaches the lateral bud—and it does reach the lateral bud! More research is needed, but that this is control by the main apex is clear enough.

We have now considered the first of our two possible explanations for the discrepancy between the actual number of branches in the crown of a tree and the number to be expected on the basis of Wiesner's calculations, and we have seen that lateral buds often fail to grow out. This fact, however, goes only a little way towards explaning the paucity of branchlets on the lower parts both of the trunk and of the main branches of a typical bushy-top tree. We must therefore explore the second of our suggested explanations, that some lateral shoots die and drop off. This is in fact a very well-known phenomenon to which the term 'cladoptosis' or 'branch-fall' has been applied. Branchlets of size and form characteristic of the species may often be found in great numbers beneath a large tree, and usually the broken surface is covered with a corky abscission-layer. The branchlets that fall in this way are chiefly from the interior of the crown, where the light-intensity is lower than at the periphery. This does not necessarily mean that the branchlets die and drop off merely because they cannot photosynthesize enough to compensate for their respiratory losses: branch-fall is the result of an active process, a correlative inhibition and killing by more vigorously growing branches nearby. This was demonstrated by the Belgian botanist Massart in the early years of the century. He showed that if one branch of an otherwise well-illuminated young tree of the Norfolk Island pine (*Araucaria excelsa*) is shaded it will soon die, even though a similarly reduced light intensity affecting the whole tree will permit survival in a quite healthy state. With the whole tree shaded no branch dies: with only one branch similarly shaded, that branch dies. R. Snow made a close examination of this phenomenon in herbaceous plants, and especially in the garden pea (*Pisum sativum*) during the period 1931-7. By decapitating young pea seedlings he prepared plants with two shoots springing from the axils of the cotyledons. In such plants, if one of the shoots has its leaves removed until only those one millimetre or less in length remain, it is rapidly arrested in growth and finally killed. This effect, moreover, must be due to inhibition coming from the intact shoot, for if similar *single* shoots are similarly defoliated they grow on rapidly and indefinitely. More recently T. Sachs has used the same material but with the difference that he selected decapitated plants in which the shoots growing from the cotyledonary axils were of markedly different lengths. He then found that the smaller of the two was inhibited and soon showed signs of senescence. If, however, the larger was removed, the surviving smaller shoot was no longer inhibited in its growth. Replacement of the larger shoot by lanoline containing IAA caused inhibition to persist, but the application of kinetin to the smaller shoot protected it from inhibition. Yet again, therefore, we find a hormonal mechanism by means of which vigorously growing apices control the growth of neighbouring weaker shoots: yet another example of apical tyranny. Its effect on the forms of trees is profound. It explains why trees growing in close canopy develop long clean boles, and why their main branches are also devoid of branchlets up to a short distance from the periphery of the crown. It thus explains the distinction between the 'pioneer' form and the 'high forest' form of trees.

C. Poplars

The 'poplars' of my Home Guard classification are the Lombardy poplar (*Populus nigra* cv. *italica*), with a characteristically narrow columnar habit. The lateral branches ascend at a very small angle with the vertical but are relatively short. Little is known about the physiological reasons for the striking difference in form between this fastigiate cultivated variety and the wild and normally spreading *Populus nigra*. There has, presumably, been some genetic changes in the hormonal control of growth of the lateral branches, apical dominance being expressed exclusively as an inhibition of elongation-growth of the laterals and not at all as an imposed plagiotropism. Many other tree species have fastigiate forms resembling the Lombardy poplar, though few are as extreme. At the other end of the sacle are the even more numerous weeping or pendulous forms of tree species. These have been somewhat more extensively studied than fastigiate forms, though not much in modern times. It is clear, however, that they constitute a very heterogeneous group, differing in details of behaviour and presumably also in the structural and hormonal mechanisms responsible for their aberrant mode of growth. In some there is an active downward growth of branches, as though the downward curvature-tendency were presistently dominant. In others the tips of branches are always upturned and it seems that the pendulous habit is caused either by a mechanical weakness of the branches, so that they droop under their own weight, or by an unusually late development of a strong downward curvature-tendency. It is possible that both factors operate, and in different degrees in different species, but there is no reasonable doubt that part of the story is a change in the nature of the control by the main apices, that it is still a mattter of correlative phenomena. There is a wide and interesting field here for further experimental investigation.

There is, of course, much more that might be said about the determination of the shapes of trees, but I hope I have been able to show that control by main apices plays a very important part. To see what happens when that control is seriously disturbed look at a tree that has been invaded by the pathogens responsible for 'witches' brooms', where all existing buds, and newly arisen buds as well, grow out into a dense tangle of branchlets. Imagine the whole tree affected in that way, and you will then understand how fundamental to tree physiology is the normal integration through tyranny of the main apices. You may well feel that the word 'tyranny' is badly chosen: the better analogy might be a benign rule by a paternal dictator with equally paternal subordinates.

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