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COVER PHOTOGRAPHS

Past General Presidents of ISCA

1. Sir U. N. Brahmachari (1936)
2. R.B.T.S. Venkatraman (1937)
3. Prof. Rt. Hon. Lord Rutherford of Nelson *(1938)
4. Sir James H. Jeans (1938)
5. Prof. J. C. Ghosh (1939)
6. Prof. B. Sahani (1940)
7. Sir Ardeshir Dalal (1941)

* Lord Rutherford unfortunately passed away before the Science Congress and Sir James H. Jeans presided over the Congress in his place.

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EDITORIAL

Social Network Analysis (SNA) is a "new comer" so to say, in the field of social science research in our country though it has jutted out of mainstream sociology during nineteenth-early twentieth century. It may have taken (perhaps) some time to carve out a place for itself with its own concepts and tools in methodology of social science and get firmly established as a distinctly identified stream of research. But its roots are anchored in the nineteenth century writings of the founding fathers of History of Civilisation, Sociology, Anthropology, Ethnography and Jurisprudence—Lewis Morgan, Henry Maine, Ferdinand Tönnies, August Comte, Herbert Spencer, Emile Durkheim, Georg Simmel are only some among them. Rightly has Don Martindale thought of the nineteenth century "as the age of social science" (*The Nature and Types of Sociological Theory,* Houghton Mifflin Company, Boston, 1960, p. 43). From empirical evidences its application has been traced farther back to linking of families by marital ties in Florence (Dutta, Bhaskar and Jackson, M. O. "On the formation of networks and groups", in their ed. : *Networks and Groups Models of Strategic Formation*, Springer Verlag, Berlin, 2003, 1-15).

Irrespective of geographical and temporal connotations a social network, can be pragmatically conceptualised as "an identifiable set of persons and the relationships that exist among them (Mitchell, J. C. : "The concept and use of social networks" in his ed. : *Social Networks in Urban Situations*, Manchester University Press, 1969, 1-50). The idea of social network, thus stated, makes it amenable to graph-theoretic and probabilistic analysis in which a social actor is represented by a point or vertex with a number of lines linking any pair of points (a line representing the presence of a relationship and obviously there will be no line in case of absence of a relationship). Further more, an arrow is added to the lines in order to show various directions of flow of relationship among the various pairs of points. Thus, a social network becomes equivalent to a digraph. Minimally, it can depict a present-absent (i.e., 1 or 0) type of situation. Such a digraph is an "unweighted" di-graph. Otherwise, unequal values or weights can be assigned to the lines which may correspond to frequencies of occurrence of the "flow" between a pair of points, or the volume or its value, so to say, "flowing" from a point to another within a pair. Hence, one arrives at a "weighted" di-graph.

In sociological or social anthropological parlance there are many important concepts which are quite abstract to be grasped quantitatively, but can be quantified and measured with the help of social network analysis. Examples are concepts of characteristics of a society such as its solidarity and cohesiveness, connectedness, hierarchy, fragmentation and so on. The domain of SNA has no longer remained confined to only sociology or social anthropology. It has extended far beyond their boundaries. Taking cue from its logistics of social research, social scientists have endeavoured to apply the methodology of SNA to diverse areas of studies in social and behavioral sciences like decision making and problem solving in a group ; leadership ; community study ; political and economic system ; social support / insurance system ; diffusion of innovation ; study of markets, coalition formation, interlocking of directorate ; social influence, exchange and power ; epidemiology ; and many others (for a comprehensive reference one may see Wasserman, S. and Faust, K : *Social Network Analysis : Methods and Applications***,** Cambridge University Press, 1994, 1-26 ; Dutta and Jackson : op. cit ; Wellman, Barry : "The Network Community An Introduction to Networks in the global village", *Networks in the Global Village*, Boulder & Co. ; West View 1997, 1-54). SNA has also been included in graduate studies in many European and American Universities.

During last few decades application of SNA has flourished as a new addition in the field of social sciences. It has drawn attention of scientists from diverse fields to such an extent that it has become an inter-face of multi-disciplinary endeavour in the true sense of the term, by collaboration of even "hard sciences" like mathematics, statistics, computer science, on the one hand, and "soft" social and behavioral sciences such as sociology and social anthropology on the other. Theoretical base of SNA has been recently discussed comprehensively. (Turner, Jonathan H. : *The structure of sociological theory*, Rawat, Publications, Jaipur, 1987, 215-305 ; Collins, Randall : *Theoretical Sociology*, Harcourt Brace Jovanovich Publishers, London, 1988, particularly its Chapter 12 : Network Theories, 412-448). The fact of the matter is that that way social network analysis has become a new paradigm in the study of society and its various processes.

Quite appropriately its relevance for studies on Indian society was aptly discussed as early as 1964 (Srinivas, M N and Béteille, André : "Networks in Indian social structure," MAN, November–December, 1964, No. 212, 105–168). Pertinence of SNA was pointed out in the context of Indian rural scenario of "planned social change and economic development" which involved "transmission of certain key ideas, principles and values from the highest to the lowest levels of society" on the one hand, and "political mobilization" on the other. But the cue was not taken from the lead the reason of which still remains a puzzle.

One can only make a conjecture to the extent that "caste", its structural and ideological imperatives, has built in Indian social system a hierarchically structured segmentalisation. Being a unique living social system it had traditionally continued to attract the attention of sociologists and anthropologists globally. Its impact has percolated to India through scholars and researchers and thus, Caste has continued to dominate local research scene (Bandyopadhyay, Suraj : "Caste 'Lost' and Caste 'Regained' : Some Aspects of a sociology of empirical research on Village India" in Srinivas, M. N., Seshaiah, S. and Parthasarathy ed. : *Dimensions of Social Change in India*, Allied Publishers Pvt. Ltd., Bombay, 1977, 115-134). Since structural-functional theorisation provides a catchy frame of concepts and logistics for the study of such a caste-based social system in India the scholars here have, perhaps, remained obsessed with structural functionalism. Pathbreaking alternative deviation was the study of : *The Dynamics of a Rural Society* by Mukherjee, Ramkrishna (Akademic-Verlag, Berlin, 1957). The pattern variables of Talcott Parsons has missed one significant dichotomy–inert-receptive! A receptive ideology of social research needs to be cultivated in order that "soft" social sciences may flourish comprehensibly by synergisation.

Dr. S1uraj Bandyopadhyay

Every individual is a marvel of unknown and unrealized possibilities.

— Goethe

PRESIDENTIAL ADDRESS

RESEARCHES IN INDIA AND IN GREAT BRITAIN

RT. HON. LORD RUTHERFORD OF NELSON* O.M.,F.R.S., D.SC., LL.D., PH.D.
SIR JAMES H. JEANS*

During the past fifty years, the British Association for the Advancement of Science has been invited on many occasions to hold its meetings overseas. Four times it has journeyed to Canada (Montreal 1884, Toronto 1897, Winnipeg 1909, Toronto 1924), twice to South Africa (1905, 1929), once to Australia (1914). This policy of the Association of arranging occasional meetings in our Dominions has proved an unqualified success. These overseas visits have had a marked influence on the progress of Science throughout our Commonwealth and by personal contacts have helped much to promote mutual understanding and cooperation between our peoples.

The visit of a representative group of scientific men to our most distant Dominions in 1914, in itself an outstanding event in the history of the Association, was rendered even more notable by the dramatic circumstances under which the meetings were held, for the arrival of the party in Australia coincided with the news of the outbreak of the great war. No one who like myself took part in the meetings in Australia and New Zealand in those troubled but stirring times can ever forget the warmth of our reception. We were privileged to witness that wonderful response of the peoples of these lands to the call of danger—a response which we know grew ever greater with the need.

It has long been the wish of the British Association to hold a meeting in India, but difficulties of time and climate have stood in the way of its realization. It has been found most convenient for the overseas visits to take place in the summer months but such a time is quite unsuitable for India. This difficulty would be in part surmounted if a representative party of scientific men could obtain leave of absence from their duties to visit India during the cold weather.

The celebration of the Silver Jubilee of the founding of the Indian Science Congress Association offered a suitable occasion for such a visit, and arrangements have been made by the two Associations to hold a joint meeting in India. I gladly accepted the invitation of the two bodies to preside over this combined meeting. I feel it not only a great honor but a great privilege and responsibility to be asked to fill this post on such an historic occasion. This visit of the British Association to your shores is a symbol of our desire to extend the hand of greeting and fellowship to our sister society and also individually to our co-workers in Science in India.

While science has no politics, I am sure it is of good omen that our visit happens to fall at a time when India is entering upon a new and important era of responsible cooperative government in the success of which both our countries are deeply concerned.

On behalf of the British Association, I extend to the Indian Association our warmest congratulations

* Lord Rutherford unfortunately passed away before the Silver Jubilee Session of the Science Congress and Sir James H. Jeans Presided over the twenty-fifth Congress held during. 3–9 January, 1938 at Calcutta.

on this the twenty-fifth anniversary of its foundation and our sincere wishes for its continued success. We recognize that your Association, both in its constitution and its aims so closely resembling the British Association, has proved of great service to the progress of Science throughout India. Founded at a time, when the Universities were becoming centers of original research, it afforded to a widely scattered scientific community a much needed common meeting ground for the discussion of scientific problems. It helped also to bring to the attention of the interested public the importance of Science and of the scientific method in national development. I think it can be safely stated that the success of the meetings of the Indian Association in no small degree influenced the later foundation of specialist societies in India, for example, the Chemical Society and Physics Society.

On such an occasion as this, we must not forget to do honor to those who were largely instrumental in founding your Association and in guiding its infant steps. I would refer in particular to Professor J. L. Simonsen, Professor P. S. MacMohan and your senior Past-President, Sir Sydney Burrard. The Association owed much in its early days to the friendly support and encouragement so freely given by that premier Indian Society, the Royal Asiatic Society of Bengal of which I am proud to be an honorary Fellow.

In earlier days in India, research was largely confined to the great official scientific services, initiated and maintained on a generous scale by the Indian Government, for example, the Survey of India, the Geological Survey, the Botanical Survey, the Departments of Agriculture and Meteorology and many others. Pioneer work of outstanding scientific importance has been done by all these services. In the short time at my disposal, I can only make a passing reference to a few items of work accomplished, and can mention only a few of the array of distinguished names which have been connected with these great scientific services.

The Trigonometrical Survey of India has a long and distinguished history. The splendid series of geodetic measurements along an arc from Cape Comorin to the Himalayas, made by Everest, was of outstanding importance and his name is for ever associated with the highest peak in the world. As a result of this survey, the deflections of a plumb-line, due to gravitational attraction of the Himalayan range, were determined at different points. A careful comparison of the results of observation with calculation, largely due to the work of Archdeacon Pratt of Calcutta, and later of Sir Sydney Burrard, disclosed marked discrepancies, the effect of the mountain mass at a distance being much less than was expected. Attempts to explain these and other anomalies ultimately led to the formulation of a new and important theory of mountain formation known as the Principle of Isostasy. On this hypothesis, the excess pressure due to a mountain mass is compensated for by a deficiency of matter below its base. This conclusion, which is in accord with extensive gravitational as well as geodetic measurements in India, is believed to be of general application to mountain formation throughout the world.

I may recall that a former distinguished Superintendent of this Survey, Sir Gerald Lenox Conyngham, is now Head of the Department of Geodesy in Cambridge.

The Geological Survey, one of the oldest scientific services in India, has a fine record of work accomplished and its survey of the mineral resources of India has proved of great value to Indian Industry. Among many distinguished names, I may specially mention that of Sir Thomas Holland, a former Director, who has done such good work for your country in peace and war. I believe that it was largely due to his energy and scientific insight that the great Tata Iron and Steel Works were begun.

The Department of Meteorology has done much pioneering research and was one of the first to realize the importance of studying the conditions of the upper air by means of small balloons—a subject of ever-increasing importance with the advent of the aeroplane. I have always felt a friendly interest in this Department as many of its members are known to me personally. Amongst them is Sir Gilbert Walker, a former Director and once President of this Association, who did much to improve the Meteorological Service in India and himself made important original contributions to our knowledge of the South-West Monsoon. I may recall that the present distinguished head of the Meteorological Office of Great Britain, Sir George Simpson, was for many years a member of this Indian Department.

The study of the botanical riches of India owes much to the work of Roxburgh, Wallich and Prain, and also that explorer and naturalist, Hooker, whose work on the flora of British India is known to you all.

In Forestry, India has at Dehra Dun probably the finest research laboratory of its kind in the world. We in England owe a debt of gratitude to India in providing us with our distinguished Professor of Forestry at Oxford, Professor R. S. Troup and the first two directors of our Forest Products Laboratory, namely Sir Ralph Pearson and Mr. W. A. Robertson.

While in this brief survey, I can mention only a few departments out of many, yet I must not omit to refer to the great advances in knowledge due to the Indian Medical Service, so well-represented by the pioneer work of Ross on malaria and by Leonard Rogers on cholera and leprosy, researches which gave new hope to the peoples of India.

In the early days of the Indian Universities, attention was mainly directed to teaching and examining the large number of students who presented themselves and comparatively little attention was paid to research. There were always a few, however, who recognized that the universities had a wider part to play in Indian education, and should become centres of research as well as of teaching. Amongst those pioneers who distinguished themselves by original investigations and by the stimulation of others, I should particularly mention Sir Alexander Pedler, Sir Alfred Bourne, Sir Jagdis Bose and Sir Prafulla Ray, and it is of interest to recall that the last three have all been Presidents of your Association.

As a result of the Curzon Commission on Education in 1904, many of the universities introduced honours courses, and by new appointments and improvements in laboratories stimulated research in science. Excellent well-equipped schools of research have arisen in many Indian universities, where good opportunities are available for the training of potential investigators in the methods of research. The Indian student has shown his capacity as an original investigator in many fields of Science, and, in consequence, India is now taking an honourable part and an ever-increasing share in the advance of knowledge in Pure Science.

Amongst many workers of distinction, I may specially mention Sir Venkata Raman, Professor M. N. Saha and Professor B. Sahni, each of whom has made outstanding contributions. That premier scientific society of Great Britain, the Royal Society, has recognized the value of their work by election to its Fellowship.

We in Great Britain watch with pride this growth of the scientific spirit in India and are pleased to help in any way we can. As an example of our interest, I may recall that Trinity College, Cambridge—my own college assisted that mathematical genius Ramanujan to pursue his studies in Cambridge. He was soon elected a Fellow of that College and a Fellow of the Royal Society. But for his premature death, it may be said of him, as Newton said of Cotes, that we had known something.

The researches in Astrophysics of S. Chandrasekhar in Cambridge were soon recognized by the award to him of an Isaac Newton Studentship and later by his election to a Fellowship in Trinity College.

As a member of the Royal Commission for the Exhibition of 1851, I would like to refer to some events this year of special interest to India. This Commission awards each year a number of Overseas Scholarships to our Dominions, as well as Senior Research Studentships open to competition in England by all members of our Commonwealth. The opportunity offered by these scholarships to promising investigators from overseas to continue their work in England or abroad has proved of great value to the progress of Science. I am proud to remember that I myself was awarded an 1851 Scholarship on the recommendation of University of New Zealand.

It has for some time been the wish of the 1851 Commission to be able to offer one or more of its Overseas Scholarships for award to students in India. Owing to difficulties of finance, it was only this year that this project was realized. a preliminary committee of selection was set up in India and the Commissioners with whom lay the final choice have appointed Mr. N. S. Nagendra Nath of the Indian Institute of Science, Bangalore, as the first 1851 Exhibition Scholar from India. He will proceed to Cambridge to carry out investigations in Theoretical Physics. For the first time also, an Indian student in Cambridge, Dr. H. J. Bhabha, has been awarded in open Competition one of our valuable Senior 1851 Studentships in recognition of the importance of his researches in Theoretical Physics. The Commission would like to be in a position to allot a second Science Scholarship to India but funds are insufficient. The machinery, however, is there, and I know that the Commissioners would be only too happy to administer a second award if anyone in India, who is interested in her scientific progress, were generous enough to provide the necessary endowment.

While, as we have seen, the universities of India have in later years made substantial progress both in teaching and research in Science, yet it must be borne in mind that still greater responsibilities are likely to fall on them in the near future. This is in a sense a scientific age, where there is an ever-increasing recognition throughout the world of the importance of Science to national development. A number of great nations are now expending large sums in financing scientific and industrial research with a view to using their natural resources to the best advantages. Much attention is also paid to the improvement of industrial processes and also to conducting researches in Pure Science which it is hoped may ultimately lead to the rise of new industries.

It is natural to look to the universities and technical institutions for the selection and training of the scientific men required for this development. In India, as in many other countries, there is likely to be a greater demand in the near future for well-trained scientific men. With the growth of responsible government in India, it is to be anticipated that the staff required for the scientific services in India and for industrial research will more and more be drawn from students trained in the Indian universities. It is thus imperative that the universities should be in a position not only to give a sound theoretical and practical instruction in the various branches of Science but, what is more difficult, to select from the main body of scientific students those who are to be trained in the methods of research. It is from this relatively small group that we may expect to obtain the future leaders of research both for the Universities and for general research organizations. This is a case where quality is more important than quantity, for experience has shown that the progress of Science depends in no small degree on the emergence of men of outstanding originality of mind who are endowed with a natural capacity for scientific investigation and for stimulating and directing the work of others along fruitful lines. Leaders of this type are rare but are essential for the success for any research organization. With inefficient leadership, it is as fatally easy to waste money in Applied Research as in other branches of human activity.

The selection of such potential investigators and leaders is not an easy task, for success in examinations in Science is no certain criterion that the student is fitted for a research career. A preliminary training in research methods for a year or two is required to select those who possess the requisite qualities of originality and aptitude for investigation. A system of grants-in-aid or scholarships to approved students may be required for such postgraduate training. In Great Britain the financial help given by the Universities and other educational institutions for training in research is in many cases supplemented by maintenance grants to promising students, awarded by the Department of Scientific and Industrial Research. This system has proved of much value both in developing the research activities of the universities and in providing a supply of competent men both for research in Pure Science and in industry.

I have so far mentioned some aspects of the scientific work carried out by the universities and government services of India. I am well aware that much attention has also been directed to the need of scientific research in agriculture, and in certain industries. An Indian Cotton Committee has been set up which has given admirable service, while the Indian Lac Cess Committee arranges for investigations in that unique Indian product, some of which are carried out in Great Britain. I am interested to know that an Agricultural Research Council has recently been formed, largely as a result of the findings of a Commission of which his Excellency the Viceroy was Chairman.

While I cannot lay claim to have any first-hand knowledge of Indian industries and conditions, yet perhaps I may be allowed to make some general observations on the importance in the national interest of a planned scheme of research in Applied Science. If India is determined to do all she can to raise the standards for the life and health of her peoples and to hold her own in the markets of the world, more and more use must be made of the help that Science can give. Science can help her to make the best use of her material resources of all kinds, and to ensure that her industries are run on the most efficient lines. National research requires national planning. If research is to be directed in the most useful direction, it is just as important for a nation as for a private firm to decide what it wishes to make and sell. It is clear also that any system of organized research must have regard to the economic structure of the country. One essential fact at once stands out. India is mainly an agricultural country, for more than three-quarters of her people gain their living from the land, while not more than three per cent are supported by any single industry. A glance at the official review of the trade of India shows that the annual production of wheat has risen since 1914 from about 8.3 to 9.5 million tons, while exports in the same period have fallen from over a million tons to 10,000 tons. In the case of another important food, rice, the Indian production, exclusive of Burma, has remained fairly steady, varying between 22 and 25 million tons annually, but here also exports have fallen from about half a million tons before the war to about 200,00 tons.

In view of these facts, it would seem clear that, in any national scheme of research, research on foodstuffs has a primary claim on India's attention. Quite apart from improvements in the systems of agriculture used in India, there is a vast field for the application of scientific knowledge to the improvement of crops, for example, by seeking for improved strains suitable for local conditions, by research on fertilizers and in many other directions. The fact that surplus wheat for export has decreased suggests that the present production is required for home consumption in India. When the permanent schemes of irrigation now in hand bring much more land under full cultivation, India may again wish to take her place in the export market. To do this in the face of international competition, well-planned agricultural research will be essential.

While the character of India's trade has seen many changes in the last hundred years, today exports of cotton, jute and tea amount to about 60 per cent of the total exports of India. Next in importance come oil and seeds 6 per cent, hides 5 per cent and lac 1 per cent. There is no doubt that more scientific knowledge would increase the production of all these products. There is of course the need to make sure that there is a market for such a surplus. Of India's standard exports, cotton represents about 20 per cent of the total value. In spite of recent strenuous attempts to improve Indian cotton, its staple is still usually looked upon in the world's markets as short and coarse. No doubt there are purposes for which cotton of this type possesses special advantages, though the demand for it must now be very near to saturation point. Still, India only produces about 16 per cent of the world's cotton crops and there appears to be no reason why it should not produce a larger share ; but until the cultivation of better varieties is more extensive, competition with cottons of the American type in the world markets will certainly be difficult. Here there appears to be a wide field for applied research. Good work has been done by the Indian Cotton Committee which has taken steps to improve the staple and prevent adulteration and inter-mixture of various varieties. The problem can be approached, however, not only in the seeking of better varieties but in finding uses and methods of treatment for the short staple variety. The importance of research on the cotton itself is well brought home by the results achieved in the United Kingdom, where the British Cotton Industry Research Association at the Shirley Institute has found that many of the defects which appear in the finished article can be traced back to defects in the raw material.

Finally a word might be said concerning the need for research on radio communication, so important a matter to a large country like India. I do not refer to technical research in transmitting and receiving apparatus, but rather to the type of fundamental investigation pursed under the Radio Research Board in Great Britain. These investigations, begun in the early days after the war, have shown that the propagation of radio-waves over large distances is very sensitive to the electrical state of the upper atmosphere. It is now established that a number of electrified layers exist in the higher atmosphere which under certain conditions are able to reflect electric waves. The details of this electrical distribution vary considerably with the hour of the day and with the season of the year, as well as with geographical location. Such information, which is of practical importance in the selection of the most suitable wavelengths for radio-communication, must obviously be secured by research conducted in the country itself. Moreover, it does not seem impossible that such a survey may prove of value of long-range weather forecasting.

There is here, then, much scope for research in a wide field, which I hope will be pursued vigorously in India. It is pleasant to note that a most promising beginning in tacking fundamental radio problems of this character has already been made here by Professors M. N. Saha and S. K. Mitra and their students. The importance of survey work of this kind has already been recognized in other parts of the Empire, where it has received official support and encouragement. I will refer in particular to the admirable work in this field by the Radio Research Board of Australia.

Industrial Research in Great Britain

While I recognize the great differences which exist between the industrial and agricultural conditions in Great Britain and India, yet it may prove of some interest and, I hope, of some value, if I give a brief account of some of the ways in which the British Government has aided industrial and agricultural research in the period following the great war. From the dawn of the scientific age, Great Britain has taken a prominent place in advancing knowledge both in pure research in our universities and in applied research for the development of industry. Before the war, progress in industry depended in the main on the brilliant contributions of individual workers rather than on any systematic attack by scientific methods on the problems of industry. We may instance the pioneer work of Bessemer for the steel industry and of Parsons in the development of the steam turbine which had such a great effect on the power industry. One cannot pay too high a tribute to the greatness of the achievements of individual inventors and investigators such as these, for it was largely due to them that Great Britain obtained so great an industrial position in the last century.

Yet I think it is true to say that in the period before the war the country as a whole failed to recognize as fully as some other nations the importance of an organized scientific attack on broad lines on the problems of industry. In a number of cases, British Science gave ideas to the world, but it was left to other nations to develop them by intensive research and to reap the industrial benefit.

This weakness in our organization became apparent in the war when the production of munitions and materials threw a great strain on industry. The Common danger brought the industrialist and man of Science into close cooperation to their mutual benefit. The result of this cooperation surpassed all expectation. New chemical processes were evolved ; many new devices arose, while communications were revolutionized by the rapid development of the thermionic valve. In a hundred different ways, the cooperation of Science with industry had justified itself by its success.

Early in the war, the British Government recognized that when peace came, a more systematic application of Science and research over a broader field was essential in the national interest and, amid the distractions of war, set up the necessary machinery to accomplish this. In 1915 the Department of Scientific and Industrial Research was formed, and a few years later in 1920 the Medical Research Council was set up to undertake investigations in all matters connected with the health of the people. This was followed in 1931 by the formation of the Agricultural Research Council. The formation of the Department of Scientific and Industrial Research marked the first comprehensive and organized measure taken in Great Britain to help industry generally through the application of Science. A number of new research organizations were set up, controlled and financed by the Department, to deal with the scientific aspects of the use of fuel, of the storage and transport of food, of buildings and later of roads—subjects of great importance to the common welfare of the people but on which little if any organized research had been undertaken.

Coal is the greatest material asset possessed by Great Britain, for on it mainly depends the heating of our homes and the production of power for most industries. Its better utilisation is a problem of great national importance. To achieve this purpose, the Fuel Research Board was formed and a large laboratory was erected at Greenwich to carry out investigations on the better and more economic use of coal. An important section of this work is a national survey of the coal resources of Great Britain carried out in special laboratories in the several coalfields. The properties of the coal in the various seams are carefully examined and, if necessary, full-scale trials are made at the Fuel Research Station to test the suitability of the coal, for example, for carbonization, for steam raising or for conversion into oil. The results of this survey, which is still in progress, have proved of increasing value not only to the colliery owner and the industrialist but also for the needs of the export trade.

In Great Britain every year upwards of 100 million pounds are spent on the erection of new buildings and in maintaining old ones, yet no organized research on buildings had been made. To remedy this deficiency, the Department set up a Building Research Station near London where investigations are made on the many and varied problems connected with the better housing of the people. For example, investigations are carried out to find a scientific explanation of the traditional practices which have grown up in the building trade, for on this depends a rational adjustment of materials and methods to meet modern needs. The results of such a scientific enquiry in this comparatively unexplored field cannot fail to have a marked influence on building construction generally.

The Building Research Station embraces in its programme all problems connected with building materials except those associated with the use of timber. These are dealt with at another establishment of the Department, the Forest Products Research Laboratory. Here intensive researches are carried out on the best use of timber and its preservation. The country spends large sums annually on timber, much of it imported, and in the national interst it is of great importance to us that the best value is obtained for this outlay.

You are all aware that food represents one of Great Britain's largest imports, and much of this is transported great distances from overseas. An organization was set up known as the Food Investigation Board, to consider the best methods of storage and transport of food, so as to avoid waste and loss of nutritive value. Much of this work has its centre at the Low Temperature Research Station in Cambridge, but a special station at Torry, Aberdeen, deals with the preservation of fish and another at Ditton in Kent with the storage of fruit. Investigations in this field, which owe so much to the initiative of the late Sir William Hardy, have proved very valuable in many directions, and have led to great improvements in the conditions of transport and storage of a great variety of food stuffs.

I may give one example out of many of the striking consequences of such researches. The Low Temperature Research Station found that beef in a chilled state could be safely stored for 60 or 70 days in a suitable atmosphere of carbon dioxide. The importance of this discovery, which enabled beef to be carried in first rate condition from our most distant Dominions, was at once recognized by the interests concerned. The first shipment of chilled beef carried by this new method of gas storage was landed in 1929 from New Zealand. Since that time, shipments from Australasia have steadily increased, and most of the vessels built for the Australsian trade have now chambers specially constructed for transport in gas storage.

While the development of our roads in the past owes much to the pioneer work of men like Macadam and Telford, there was no planned organization to add to our knowledge of road construction until comparatively recent years, when the Road Research Station was set up at Harmondsworth near Slough to deal with problems of road construction and the study of road wear under modern conditions of traffic. When we consider the large sums spent every year on the construction and maintenance of roads, the need of such scientific investigation is obvious.

The group of research organizations so far considered deals with the primary needs and interests of the people as a whole as regards food, fuel, building and roads. No independent estabishment was set up to deal with another important need of the people, namely clothes, for this is most appropriately provided for by the large research associations which have been instituted in connection with the cotton, wool and linen industries.

Of the national organizations under the charge of the Department, the largest and probably the most important is the National Physical Laboratory at Teddington, which covers about 50 acres and employs a staff of nearly 700 persons. The work of this Laboratory, primarily intended for the assistance of industry in general, covers a very wide field. It has eight great departments devoted to the study of the different branches of Physics, Electrotechnics, Engineering, Metallurgy and Metrology, Radio Communications, Aerodynamics and the investigation of ship design. The Laboratory is responsible for the maintenance of the National Standards and for refined measurements connected with them. It is not always realized to what a great extent modern mass production depends on the maintenance of exact standards and the Laboratory plays an important part in testing the accuracy of gauges so necessary in modern indsutry.

In 1925 a Chemical Research Laboratory was set up at Teddington, in which pioneer work is being carried out on chemical reactions at high pressures and temperatures and in the production of synthetic resins. Another important problem in which the Department is interested is the provision of more plentiful supplies of pure water for domestic and industrial consumption. Valuable work has been done by the Water Pollution Research Board in many directions, and new methods have been found for the purification of water which has been contaminated by the industrial effluents from sugar and milk factories.

I have so far mentioned research organizations which have been set up to encourage the application of Science to problems which affect the daily life of the people and the nation's industries considered as whole. I should mention that these national organizations to which I have referred are not only willing but anxious to cooperate with corresponding institutions which may be set up in India or the Dominions.

I must now refer to arrangements which have been made to promote the application of scientific knowledge to the problems of the individual industries. The importance of research has long been recognized by large industrial companies, who have in many cases set up research establishments for their own requirements. This tendency is specially marked in the electrical and chemical industries, where large sums are spent annually on research.

It is, however, to be borne in mind that a great part of British industry is carried out in small establishments. A survey carried out some years ago indicated that in 128,000 factories in Great Britain less than 500 employed more than 1,000 workers while over 117,000 employed less than 100 workers. Obviously such small factories are not in a position to maintain a research laboratory on anything but a small and inefficient scale. To overcome this difficulty, the Department in conjunction with industry instituted a number of cooperative research associations representing the greater part of the main industries of the country. Each of these research associations is autonomous and controlled by representatives of the industry concerned, and is financed by contributions from the firms belonging to the association, assisted by grants from the Department.

This bold experiment in the cooperative organization of research, which is unique in the world, has undoubtedly proved a great success. Today there are twenty such research associations formed on a national basis in their respective industries and for membership of which all British firms are eligible. They cover the metal and textile industries, paint, leather, boots and shoes, rubber, flour milling, cocoa and confectionery, food, printing, scientific instruments and the automobile and electrical industries. From small beginnings, a number of these associations have steadily grown in size and strength until they now form an indispensable and valuable part of the industries they represent.

I can speak with some knowledge of the marked progress made by these two types of research organization, as I have been privileged, as Chairman of the Advisory Council of the Department of Scientific and Industrial Research for the past 8 years, to come in close contact with them. While much still remains to be accomplished, there has been a great advance in recent years in the recognition of the value of research in increasing the efficiency of industry. If we are to hold our own in face of the ever-increasing competition in the world today it is essential that our industries should take full advantage of the resources which Science places at their disposal.

It is of interest to note that the Overseas Dominions have not been slow to appreciate the importance of such national organizations in the development of their national resources and industries. Healthy research organizations under the control of National Research Councils or corresponding bodies have been set up in canada, Australia, New Zealand and South Africa. Both in Canada and Australia, which have a Federal system of Government, the research organization is national in the true sense of the word, and responsible only to the central Government.

It is to be borne in mind that the organization of research for industry and for general national purposes varies much in different countries. A research organization which may prove adequate for a country like Great Britain may prove quite unsuitable for another country with different needs and different industrial conditions. In developing any organized scheme of research, each country must consider its own resources and its own particular requirements. As we have seen, the organization of research not only in Great Britain but in the Dominions, is national in scope. Even in a large country like India, where the resources and needs of the different Provinces are very varied, it seems to me essential for efficiency that the organization of research should be on national rather than on provincial lines. The setting up of separate research establishments for similar purposes in the various provinces cannot but lead to much overlapping of work and waste of effort and money. Such a central organization of research does not necessarily mean that the scientific work should all be concentrated in a single laboratory. For example, I understand that a single organization is responsible for the research in cotton for the whole of India. While the more fundamental research is done at a conveniently situated laboratory, much of the work of a special character is carried out in the provinces where cotton is grown.

In Great Britain, the responsibility for planning the programmes of research, even when the cost is borne directly by the Government, rests with research councils or committees who are not themselves State servants but distinguished representatives of Pure Science and industry. It is to be hoped if any comparable organization is developed in India, there will be a proper representation of scientific men from the universities and corresponding institutions and also of the industries directly concerned. It is of the highest importance that the detailed plannings of research should be left entirely in the hands of those who have the requisite specialized knowledge of the problems which require attack. In the British organizations there is no political atmosphere, but of course the responsibility for allocating the neccessary funds ultimately rests with the Government.

In this address, I have to a large extent confined my attention to research in Pure Science, agriculture and industry. I am, however, not unmindful of the pressing needs of India to alleviate the sufferings of the people from attacks of malaria and other tropical diseases. I know that India herself is giving much thought to these vital problems in which Science can give her valuable help.

Transmuation of Matter

I have so far spoken of the importance of Science as factor in national development, but before concluding my address, I would like to refer to some investigations in Pure Science in which I have been personally much interested. I refer to the successful attack on that age-old problem of the transmutation of matter which in recent years has attracted so much attention from physicists throughout the world.

I hope it may prove of interest to give a brief account of the successive stages of the growth of our knowledge of this subject, for it illustrates in a striking manner the power of the scientific method of attack on what at first appeared to be an insoluble problem. Incidentally these researches have yielded us precious information on the structure of all atoms and indeed it seems likely to have provided us with a key, so to speak, to unlock the secrets of the constitution of our material world.

Towards the close of the nineteenth century, when it seemed certain that the atoms of the elements were unchangeable by the forces then at our command, the discovery was made which has revolutionized our conception of the nature and relations of the elements. I refer to the discovery in 1896 of the radioactivity of the two heaviest elements uranium and thorium. It was soon made clear that this radioactivity is a sign that the atoms of these elements are undergoing spontaneous transmutation. At any moment, a small fraction of the atoms concerned becomes unstable and breaks up with explosive violence, hurling out either a charged atom of helium, known as an α-particle, or an electron called in this connection a β-particle. As a result of these explosions, a new radioactive element is formed and the process of transmutation once started continues through a number of stages. Each of the radioactive elements, formed in this way, breaks up according to a simple universal law but at very different rates. In a surprisingly short time, these successive transformations were disentangled and more than 30 new types of elements brought to light while the simple chemical relations between them were soon made clear.

We had thus been given a vision of a new and startling sub-atomic world where atoms break up spontaneously with an enormous release of energy, quite uninfluenced by the most powerful agencies at our disposal. Apart from uranium and thorium and the elements derived from them, only a few other elements showed even a feeble trace of radioactivity. The great majority of our ordinary elements appeared to be permanently stable under ordinary conditions on our earth. Science was then faced with the problem whether artificial methods could be found to transmute the atoms of the ordinary elements. Before this problem could be attacked with any hope of success, it was necessary to know more of the actual constitution of atoms. This information was provided by rise of the nuclear theory of the atomic structure which I first suggested in 1911. The essential controlling feature of all atoms was found to reside in a very minute central nucleus which carried a positive charge and contained most of the mass of the atom. A relation of unexpected simplicity was found to connect the atoms of the elements. The ordinary properties of an atom are defined by a whole number which represents the number of units of resultant positive charge carried by the nucleus. This varies from I for hydrogen to 92 for the heaviest element uranium and with exceptions all the intervening numbers correspond to known elements.

On this view of atomic structure, it was evident that, to bring about the transmutation of an atom, it was necessary in some way to alter the charge or mass of the nucleus or both together. Since the nucleus of an atom must be held together by very powerful forces, this could only be effected by bringing a concentrated source of energy in some way to bear on the individual nucleus. The most energetic projectile available at that time was the α-particle spontaneously ejected from radio-active substances. If a large number of α-particles were fired at random at a sheet of matter, it was to be expected that one of them must occasionally approach very closely to the nucleus of any light atom in its path. In such a close encounter, the nucleus must be violently disturbed, and possibly under favourable conditions the α-particle might actually enter the nuclear structure, resulting in a transformation of the nucleus.

This mode of attack upon the nucleus at once proved successful. I found in 1919 that nitrogen could be transformed by bombardment with fast α-particles. The process of transmutation is now clear. Occasionally an α-particle actually enters the nitrogen nucleus and forms with it new unstable nucleus which instantly breaks up with the emission of a fast proton (hydrogen nucleus) and the formation of a stable isotope of oxygen of mass 17. About a dozen of the light elements were found to be transformed in a similar way. The protons liberated in the nuclear explosions were at first counted by observing the flashes of light (scientillations) produced in phosphorescent zinc sulphide. This method was slow and very trying to the eyes of the observers. Progress however became more rapid and definite when electrical methods of counting individual fast particles were developed. These electrical counters, mainly depending on the use of electron-tubes for magnifying small currents, have now reached such a stage of perfection that we are able to count automatically individual fast particles like α-particles and protons, even though they enter the detecting chamber at a rate as fast as ten thousand per minute. By other special devices, we are in like manner able to count individual β-particles. In this connection, I must also mention that wonderful instrument the Willson Expansion Chamber which I makes visible to us the actural tracks of flying fragments of atoms resulting from an atomic explosion. These remarkable devices have played an indispensable part in the rapid growth of knowledge during the last few years. It is to be emphasized that progress in scientific discovery is greatly influenced by the development of new technical methods and of new devices for measurement. With the growing complexity of Science, the development of special techniques is of ever-increasing importance for the advance of knowledge.

Up to the year 1932, experiments on transmutation were confined to the use of α-particles for bombarding purpose. It became clear that the process of transformation was in most cases complex, since groups of protons with different but characteristic energies were observed when a single element was bombarded. This led to the conception that discrete energy levels existed within a nucleus and that under some conditions part of the excess energy was sometimes released in the form of a quantum of high frequency radiation.

The stage was now set for a great advance, and four new discoveries of out-standing importance were made in rapid succession in the period 1932-1933. I refer to the discovery of the positive electron by Anderson in 1932, of the neutron by Chadwick in 1932, of artificial radioactivity by M. and Mme. Curie-Joliot in 1933 and of the transmutation of the elements by purely artificial methods first shown by Cockcroft and Walton in 1932.

The discovery of the neutron—that uncharged particle of mass nearly —was the result of a close of the effects produced in the light element beryllium when bombarded by α-particles. It is noteworthy that the proton and the neutron, which are now believed to the essential units with which all atomic nuclei are built up, owe their recognition to a study of the transmission of matter by α-particles.

Before the discovery of the neutron, it had been perforce assumed that nuclei must in some way be built up of massive protons and light negative electrons. Theories of nuclear structure became much more amenable to calculation when the nucleus is considered to be an aggregate of particles like the proton and neutron which have nearly the same mass. There was no longer any need to assume that either the positive or the negative electron has an independent existence in the nuclear structure. We are still uncertain of the exact relation, if any, between the neutron and the proton. The neutron appears to be slightly more massive than the proton but it is generally believed, although no definite proof is available, that the proton and neutron within a nucleus are mutually convertible under certain conditions. For example, the change of a proton into a neutron within the nucleus should lead to the appearance of a free positive electron, while conversely the change of a neutron into a proton gives rise to a free negative electron. In this way it appears possible to account for the observed fact that either positive or negative electrons are emitted by a large group of radioactive elements, to which I will now refer.

In the early experiments on transmutation by α-particles it was supposed that a stable nucleus was always formed after the emission of a fast proton. The investigations of M. and Mme. Curie-Joliot showed that in some cases elements were formed which, while apparently stable, ultimately broke up slowly, exactly like the natural radioactive bodies. Most of these radioactive bodies, formed by artificial methods, break up with the expulsion of fast negative electrons, but in a few cases positive electrons are emitted. Since the presence of these radioactive bodies can be easily detected, and their chemical properties readily determined, this new method of attack on the problem of transmutation has proved of great value. Nearly a hundred of these radioactive bodies are now known, produced in a great variety of ways. Some arise from the bombardment by fast α-particles, others by bombardment with protons of deuterons. As Fermi and his colleagues have shown, neutrons and particularly slow neutrons are extraordinarily effective in the formation of such radioactive bodies. On account of its absence of charge, the neutron enters freely into the nuclear structure of even the heaviest element, and in many cases causes its transmutation. For example, a number of these radioactive bodies are produced when the two heaviest elements uranium and thorium are bombarded by slow neutrons. In the case of uranium, as Hahn and Mither have shown, the radioactive bodies so formed break up in a sucession of stages like the natural radioactive bodies, and give rise to a number of transuranic elements of higher atomic number than uranium (92). These radioactive elements have the chemical properties to be expected from the higher homologues of rhenium, osmium and iridium of atomic numbers 93, 94 and 95 respectively.

These artificial radioactive bodies in general represent short-lived varieties of the isotopes of known elements. No doubt such transient radioactive elements are still produced by transmutation in the furnace of our sun where the thermal motions of the atoms must be very great. These radioactive elements would rapidly disappear as soon as the earth cooled down after separation from the sun. On this view, uranium and thorium are to be regarded as practically the sole survivors in our earth of a large group of radioactive elements owing to the fact that their time of transformation is long compared with the age of our planet.

It is of interest to note what an important part the α-particle, which is itself a product of transformation of the natural radioactive bodies, has played in the growth of our knowledge of artificial transmutation. It is to be remembered too that our main source of neutrons for experimental purposes is provided by the bombardment of beryllium with α-particles. The amount of radium available in our laboratories is, however, very limited, and it was early recognized that if our knowledge, of transmutation was to be extended, it was necessary to have a copious supply of fast particles of all kinds for bombarding purpose. It is well-known that enormous numbers of protons and deuterons, for example, can be easily produced by the passage of the electric discharge through hydrogen and deuterium (heavy hydrogen). To be effective for transmutation purposes, however, these charged particles must be given a high speed by accelerating them in a strong electric field. This has involved the use of apparatus on an engineering scale to provide voltages as high as one million volts or more and the use of fast pumps to maintain a good vacuum.

A large amount of difficult technical work has been necessary to produce such high direct voltages, and to find the best methods of applying them to the accelerating system. In Cambridge, these high voltages are produced by multiplying the voltage of a transformer by a system of condensers and rectifiers ; in the U. S. A. by the use of a novel type of electrostatic generator, first developed by van der Graaf. Prof. E. O. Lawarence of the University of California has devised an ingenious instrument called a "cyclotron" in which the charged particles are automatically accelerated in multiple stages. This involves the use of huge electromagnets and very powerful electric oscillators. By this method, he has suceeded in producing streams of fast particles which have energies even higher than α-particies ejected from radioactive substances. Undoubtedly this type of apparatus will prove of great importance in giving us a supply of much faster particles than we can hope to produce by the more direct methods.

It was at first thought that very high potentials of the order of several million volts would be required to obtain particles to study the transmutation of elements. Here, however, the development of theory of wave-mechanics came to the aid of the experimenter, for Gamow showed that there was a small chance that comparatively slow bombarding particles might enter a nucleus. This theoretical conclusion has been completely verified by experiment. In the case of a light element like lithium, transformation effects can be readily observed with protons of energy as low as 20,000 volts. Of course, the possibility of transformation increases rapidly with rise of voltage.

The study of the transmutation of elements by using accelerated protons and deuterons as bombarding particles has given us a wealth of new information. The capture of the proton or deuteron by a nucleus leads in many cases to types of transmutation of unusual interest. For example, the bombardment of the isotope of lithium of mass 7 by protons leads to the formation of a beryllium nucleus of mass 8 with a great excess of energy. This immediately breaks up with two α-particles shot out in nearly opposite directions. When boron of mass 11 is bombarded by protons, a carbon nucleus of mass 12 is formed which breaks up in most cases into three α-particles. The deuteron is in some respects even more effective than the proton as a transmuting agent. When deuterons are used to bombard a compound of deuterium, previously unknown isotopes of hydrogen and of helium of mass 3 are formed, while fast protons and neutrons are librerated. The bombardment of beryllium by very fast deuterons gives rise to plentiful supply of neutrons. Lawrence has shown that the bombardment of bismuth by very fast deuterons leads to the production of a radioactive bismuth isotope which is identical with the well-known natural radioactive product radium E. Many artificial radioactive elements can be produced often in great intensity. For example, the bombardment of common salt by fast deuterons gives rise to a radioactive isotope of sodium. This breaks up with a half period of 15 hours, emitting not only fast β-particles but γ-rays at least as penetrating as those from radium.

If may well be that in course of time such artificial radioactive elements may prove a useful substitute for radium in therapeutic work. By these methods also, such intense sources of neutrons can be produced that special precautions have to be taken for the safety of the operators of the apparatus.

Sufficient I think has been said to illustrate the variety and interest of the transmutations produced by these bombardment methods. It should, however, be pointed out that transmutation in some cases can be effcted by transferring energy to a nucleus by means of gamma rays of high quantum energy instead of by a material particle. For example, the deuteron can be broken up into its components, the proton and neutron, by the action of the gamma rays from radium or thorium. As a result of the bombardment of lithium by protons, gamma rays of extraordinarily high energy upto 17 million volts are strongly emitted. Bothe has recently shown that these high energy rays are able to transmute a number of atoms, neutrons usually being emitted in the process.

Some simple laws appear to hold in all individual transformations so far examined. Nuclear charge is always conserved, and where heavy particles are emitted, so also is energy when account is taken of the equivalence of mass and energy. Certain difficulties arise with regard to the conservation of energy in cases where light positive and negative electrons are emitted during transmutation, and there is still much discussion on this important question.

The study of the transmutation of matter has been extraordinarily fruitful in results of fundamental importance. In addition to the α-particle, it has disclosed to us the existence of those two building units of nuclei, the proton and neutron. It has greatly widened our conception of the varieties of atomic nuclei which can exist in nature. Not only has it led to the discovery of about one hundred new radioactive elements, but also of several stable isotopes of known elements like ^{3}H, ^{3}He, ^{8}Be which had previously been unsuspected. It has greatly extended our knowledge of the ways in which nuclei can be built up and broken down, and has brought to our attention the extraordinary violence of some of the nuclear explosions which occur. The great majority of our elements have been transmuted by the bombardement method, and in the case of the light elements which have been most carefully studied, a great variety of modes of transmutation have been established.

Rapid progress has been made but much still remains to be done before we can hope to understand the detailed structure and stability of different forms of atomic nuclei and the origin of the elements. I cannot but reflect on the amazing contrast between my first experiment on the transmutation of nitrogen in the University of Manchester in 1919 and the large-scale experiments on transmuation which are now in progress in many parts of the world. In the one case, imagine an observer in a dark room with very simple apparatus painfully counting with a microscope a few faint scintillations originating from the bombardment of nitrogen by a source of α-particles. Contrast this with the large scale apparatus now in use for experiments on transmutation in Cambridge. A great hall contains massive and elaborate machinery, rising tier on tier, to give a steady potential of about two million volts. Nearby is the tall accelerating column with a power station on top, protected by great corona shields—reminding one of a photpgraph in the film of Wells's "*Things to Come*". The intense stream of accelerated particles falls on the target in the room below with thick walls to protect the workers from stray radiation. Here is a band of investigators using complicated electrical devices for counting automatically the multitude of fast particles arising from the transformation of the target element or photographing with an expansion chamber, automatically controlled, the actual tracks of particles from exploding atoms.

To examine the effect of still faster particles, a cyclotron is installed in another large room. The large electromagnet and accessories are surrounded with great water tanks containing boron in solution to protect the workers from the effect of neutrons released in the apparatus. A power station nearby is needed to provide current to excite the electromagnet and the powerful electric oscillators.

Such a comparison illustrates the remarkable changes in the scale of research that have taken place in certain branches of Pure Science within the last twenty years. Such a development is inevitable, for, as Science progresses, important problems arise which can only be solved by the use of large powers and complicated apparatus, requiring the attention of a team of research workers. If rapid progress is to be made, such teamwork is likely to be a feature of the more elaborate researches in the future. Fortunately there is still plenty of scope for the individual research worker in many experiments of a simpler kind.

The Science of Physics now covers such a vast field that it is impossible for any laboratory to provide up-to-date facilities for research in more than a few of its branches. There is a growing tendency in our research laboratories today to specialize in those particular branches of Physics in which they are most interested or specially equipped. Such a division of the field of research amongst a number of universities has certain advantages, provided that this subdivision is not carried too far. In general, the universities should be left free as far as possible to develop their own lines of research and encouraged to train young investigators, for it cannot be doubted that vigorous schools of research in Pure Science are vital to any nation if it wishes to develop effectively the application of Science, whether to agriculture, industry or medicine. Since investigations in modern Science are sometimes costly and often require the use of expensive apparatus and large-scale collaboration, it is obviously essential that adequate funds should be available to the universities to cover the cost of such researches.

In this brief survey, I have tried to outline the contributions to scientific knowledge made in India, and the needs of the immediate future if Science is to play its part in the national welfare. While the study of modern Science in India is comparatively recent, and naturally much influenced by Western ideas, it is well to recall that India in ancient days was the home of a flourishing indigenous Science which in some respects was at the time in advance of the rest of the world.

The study of ancient writings has disclosed in recent years the extent and variety of these scientific contributions. Much progress was made in the study of Arithmetic and Geometry, while the researches of Sir Prafulla Ray have brought to light the important advances made in Metallurgy and Chemistry. May we not hope that this natural aptitude for Experimental and Abstract Science, shown so long ago, is still characteristic of the Indian peoples, and that in the days to come India will again become a stronghold of Science, not only as a form of intellectual activity but as a means of furthering the progress of her peoples.

ETHANOL PRODUCTION FROM STARCHY GRAINS

Shiva C. Aithal+ and D. N. Kulkarni*

Grains are the most important food-energy source for three-fourths of the world population. These grains are starchy agricultural renewable resources, which have the potential to serve as a low cost and abundant feedstock for production of industrial alcohol, a key industrial chemical, which is rapidly gaining the status of fuel. Starchy substrates employed as raw materials for ethanol production cannot be directly fermented to ethanol. This is because yeasts, which are employed for fermentation, cannot utilize the starch, hence prior to fermentation, are needed to hydrolyze it to simpler fermentable sugars. Enzymes can be employed for hydroloysis, which include amylases and amyloglucosidases from either fungal or bacterial origin.

INTRODUCTION

Chief among the grains are wheat, rice, corn, barley, oats, rye, sorghum and millet which are widely used as food for humans and animals, both directly and in processed forms. Use of grains in non-food products has significantly grown as the health, environmental and economic benefits increase. Grains are a rich and cheap source of starch. Starch finds applications in food, pharmaceutical, textile and paper industries. Grain starch can be processed for production of dextrose, maltose, high fructose syrups, etc. Grains and grain starch are used for various fermentations such as ethanol, citric acid, lactic acid, erythritol and sorbitol. In developed countries, large quantities of maize (Zea mays L.) are produced and processed for these applications. USA producted 260 million tons of maize in 1998 of which around 20% was used for production of starch, high fructose corn syrup, glucose and dextrose, fuel and beverage alcohol, and breakfast cereals.

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STARCHY MATERIALS

Starchy materials like grains usually produce the most alcohol on a weight / weight basis. Starchy materials require the steps of : (a) milling-to free the starchy material from, for example, grain kernels ; (b) dilution ; (c) cooking to dissolve and "gelatinize" the starch ; and (d) conversion of the starch to fermentable sugars, in addition to the steps of fermentation and distillation. Starchy materials fall into two main categories : (1) materials, such as grains, in which the starch is encased or protected by grain hulls ; and (2) those materials, such as potatoes, where the starch is more readily available. Milling or grinding the material to expose the starch is necessary for the former group, but not the latter. There are two basic methods of conversion. The first uses malt or an extract of the enzymes contained in malt and the second uses dilute acid in a process called "acid hydrolysis". Starchy materials generally require processing prior to fermentation. Exceptions are materials, such as potatoes and sweet potatoes, which do not require milling and materials, such as artichokes, that do not require conversion. Relatively high alcohol yields often offset the necessary additional manufacturing steps, and most starchy materials are good alcohol sources.

PROCESSING OF HYBRID SORGHUM

Sorghum grain fetches lower price when used for animal feed and the quantity used for starch production is very small. Therefore, there is an opportunity for using hybrid (blackened) sorghum for production of alcohol. This will help the poor farmers, because they will get a good price for their produce. The general procedure for converting hybrid sorghum into ethanol, as done in our laboratory with the help of enzymes, is preferable to acids, even though acid hydrolysis yields D-glucose, the hydrolysis reaction on starch is partial and additional products arising from decomposition and dehydration of D-glucose may not facilitate the direct fermentation of such sugars. On the contrary, enzymes hydrolyze the starch completely and also retard the formation of reversion and decomposition products in the syrup[1]. Thus enzyme hydrolysis was found to be more efficient than acid hydrolysis for hybrid sorghum starch. The procedure for other materials and other enzymes will differ slightly, and the manufacturer's recommendation should be followed. After milling, the grain is partially diluted (slurried) at a ratio of 30% w/w with water. The pH is adjusted to about 6.5 as optimum range for "Premalting" or liquefaction. This is accomplished by the addition of 1% v/v thermostable amylase enzyme.

The mash is then slowly heated. Gelatinization will begin at about 60-70°C and the mash will rapidly thicken. Constant stirring is necessary at this point. At about 100°C the liquefying action of the enzyme will begin. Heating may be more rapid after the liquefying action of the enzyme begins to take effect. After the mash reaches 110-120°C, the reaction is stopped, cooled down, the pH is changed to 4.5 and 1% amyloglucosudase is added to facilitate sachcharification process. This enzyme completes the conversion in about 48 hours and after cooling, the mash is fermented with the help of a consorted culture of *Saccharomyces cerivisiae* and *S. carlsbergensis* to obtain ethanol.

PRODUCTS FROM ALCOHOL FERMENTATION

CO_2 : One-half of the fermenting sugar is converted to carbon dioxide. It can be used for industrial application or in greenhouses for increasing plant growth.

ALCOHOL : The other half of the fermenting sugar is converted to ethyl alcohol. Since it contains all the fusel oil, esters, and aldehydes, it is not good for drinking, but can be used for industrial purposes and also is a good fuel.

DISTILLER'S GRAIN : Nearly all the protein is left in the solids, so distiller's grain becomes a high-quality feed for livestock. Protein is 28-30% ; fiber is 12-13% ; and moisture is 8-12%. It can be used as a supplement to increase the protein in other feeds.

Finally, it is concluded that grain processing is an important step during the process of ethanol production, because apart from increasing the plant capacity, it also reduces the energy requirements, which is a vital factor in determining the cost of end product.

Table-1 : Ethanol yield from different grains

Starchy Grains	Ethanol Yield ($L\,T^{-1}$)	Yield	
		Grain ($T\ ha^{-1}$)	Ethanol ($L\ ha^{-1}$)
Corn	360	5.4	1,950
Wheat	340	3.1	1,054
Barley	250	2.5	625
Rice	430	5.0	2,200
Sorghum	350	3.7	1,300
Oats	240	2.4	580

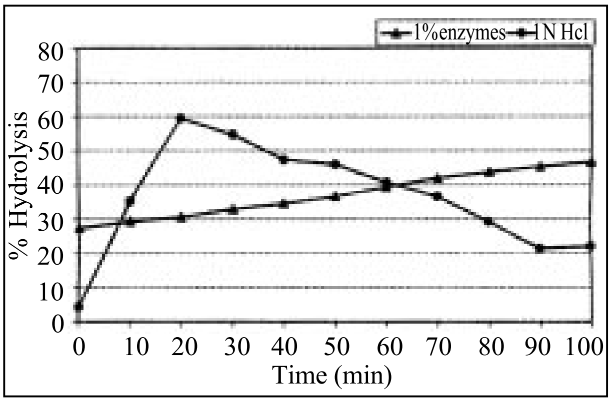
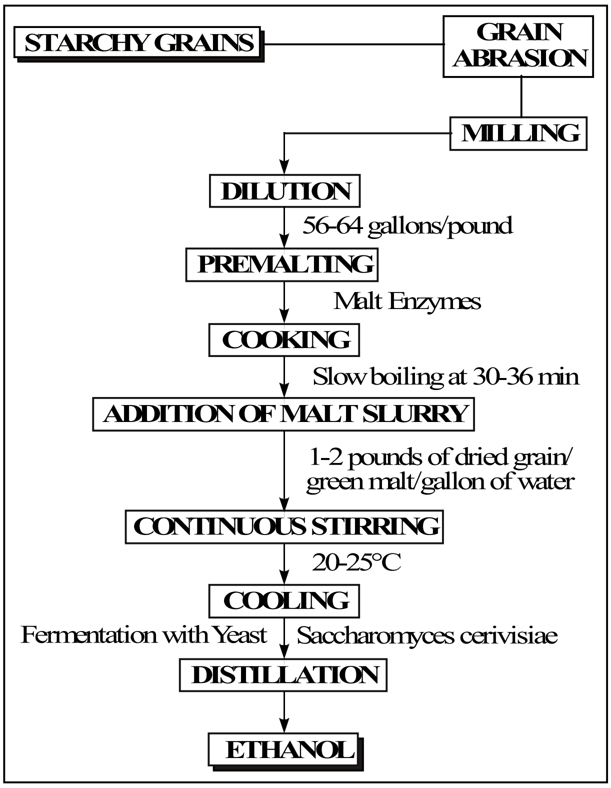
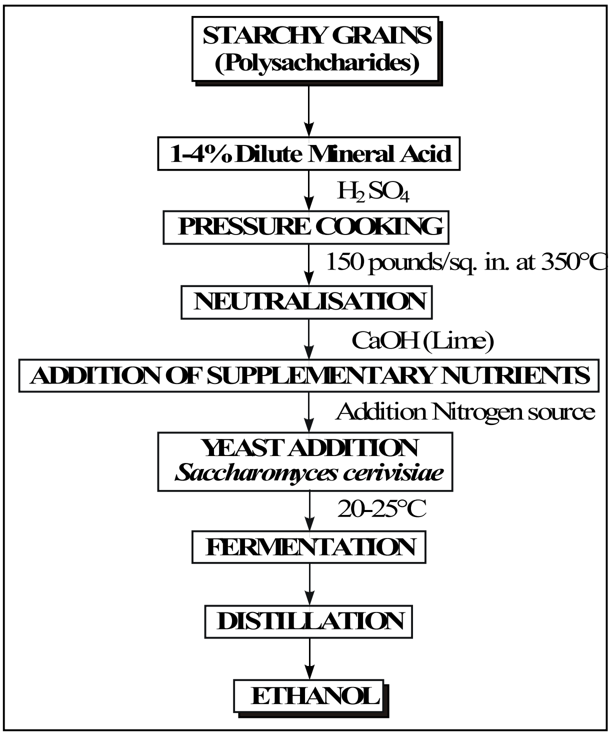


Figure 1 : Comparative profile of acid and enzyme treatment processes for hydrloysis of sorghum starch.

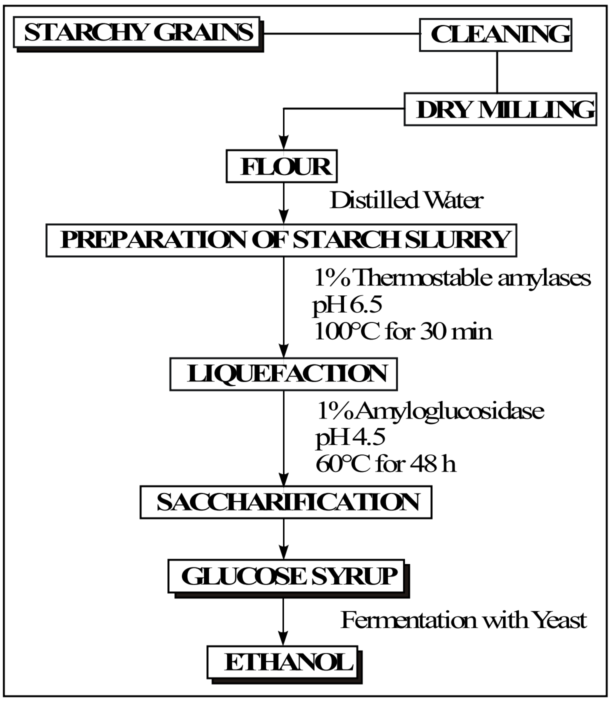
Flowchart 1 : Traditional processing of grains for ethanol production.



Flowchart 2 : Processing of starchy grains with acids.



Flowchart 3 : Processing for enzymatic processing of hybrid sorghum flour for alcohol production.



REFERENCES

1. E. Alsina, S. Valle-Lamboy, and A. V. Mondz Guz, (1975) Preliminary evaluation of ten sweet sorghum varieties for sugar production.
2. M. Bhattacharya, & M. A. Honna, *Jour. Food. Sci.* **52** : 764, 1987.
3. L. E. Casida, Jr. 1993 Industrial microbiology. Wiley Eastern Ltd., India. p 122, 1993
4. R. Dabas, V. K. Sharma, & K. Choudhari, *Ind. Jour. Microbiol.* **37**, 49-50, 1997.
5. R. Ferraris, & G. A. Stewart, *Jour. Aust. Inst. Agri. Sci.*, 156, 1979
6. K. Lorenz, J. A. and Johnson Starch hydrolysis under high temperatures and pressures. American Assoc. Cereal Chemists, Inc., Minnesota. p 616-628, 1972.
7. K. J. Lorenz, and K. Kulp, Handbook of cereal science and technology. New York, USA : Marcel Dekker Inc. p 882, 1991.

DO YOU KNOW ?

Q1. Where does sound travel faster-in air or in water ?

Q2. Where are baby hippos born in land or in water ?

NUCLEOSIDE ANALOGUES AND THEIR USE AS DRUGS

Sarika Sinha* and Ramendra K. Singh*

A surer way of inhibiting pathogen growth is to stop the duplication of its genetic material during the S-phase of mitosis that occurs prior to cell division. Molecules analogous to monomers of DNA and RNA, called Nucleoside analogues, do this very effectively. Such molecules are rapidly gaining significance in the world of therapeutics.

INTRODUCTION

Pathogenic microbes have for long duped mankind when it comes to their eradication with the use of antibiotics. They make this possible by undergoing mutations at their genomic level to synthesize better proteins and enzymes, which help them to survive in antagonistic environs and to bypass the metabolic pathways that are being interfered by the commonly used drugs. But, not anymore ! This has been made possible by the approach of **silencing pathogen genes** by bringing about damage to the genetic component of the pathogen, via molecules popularly known by the organic chemists as **Nucleoside analogues**.

WHAT ARE NUCLEOSIDES ?

Genes : the information carriers from one generation of a living species to the next, primarily comprise deoxyribonucleic acid (DNA). This DNA and its transcript, the ribonucleic acid (RNA), are made up of four standard nitrogenous bases which are ubiquitous in the living world. These bases are divided into two categories based on differences in their structure. They are the **purines**—adenine (A) and guanine (G) and the **pyrimidines**–thymine (T) and cytosine (C), found in DNA whereas uracil (U) replaces thymine in RNA. The alphabets A. G. T. & C stand for the nucleic acid bases. In the primary structure of the nucleic acids, these bases are present as **Nucleotides**. Each nucleotide consists of a **Nucleoside** (a base linked with a molecule of the cyclic sugar 2-deoxy-D-ribose in DNA and D-ribose in RNA), which is further linked to phosphoric acid. Two nucleosides are joined to each other via a **phosphodiester linkage**-the backbone of the nucleic acid polymer.

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NUCLEOSIDE ANALOGUES

Nucleoside analogues are the molecules that mimic the naturally occuring nucleosides. The mimicry lies in their structures, which are similar yet different from the molecules existing in nature.

The mechanism of action of nucleoside analogues translates itself either into the acceptance of these analogues by the enzymes responsible for the synthesis and applications of nucleic acids in a cell, or into binding of these analogues to the active sites of those enzymes in place of the natural substrates and blocking any further actions to be brought about by them[1].

Talking about the former category, the most important enzymes involved are DNA and RNA polymerases, which bring about the duplication of DNA and transcription of DNA to RNA, respectively. The nucleoside analogues, being similar in structure to the four naturally occurring nucleosides, get incorporated into the growing DNA or RNA daughter chains by bluffing these enzymes.

There after the turn of events can be divided into two categories :

(a) If the analogue carries a modification in its sugar moiety, viz. lack of 2-hydroxl or 3-hydroxyl or both, such that phosphodiester bond formation in the growing daughter chain is prevented, **chain termination** occurs. In other words, further lengthening of the nucleic acid polymer does not take place and thus DNA or RNA synthesis is prevented.

(b) However, if these analogues do succeed in bringing about completion of the nucleic acid daughter chain biosynthesis, the newly synthesized DNA or RNA chains comprising them when enter the final metabolic step of protein synthesis (translation), due to lack of exactness in the structure of these analogues, cause formation of the **defective proteins or non-functional enzymes**. These proteins and enzymes, being mandatory for the existence of the living being, when become unavailable or non-functional, the latter loses the ability to exist and proliferate. When this living species is a pathogenic microbe, these nucleoside analogues, by inhibiting its growth and multiplication by the above described mechanisms, act as **antibiotics**[2,3].

Here lies a catch to the use of these wonder drugs : Will these analogues not interfere with the nucleic acid metabolism of the host cells, which have been infected by the pathogen whose destruction is actually the aim of these molecules ? In other words, will the genetic drugs not become toxic for the patients, also living beings, who take them as medicines to get them cured of the disease being caused by the pathogen ? The answer to this ambiguity in the behavior of the drug lies in **selectivity**, that is, these nucleoside analogues should selectively inhibit the growth of the disease-causing pathogen and not the host cell. Here comes the role of **drug designing**, another vast and indispensable field of pharmaceutical chemistry. **Cell Biologists** and **biochemists** also have profound roles to play when the problem of selectivity comes up ; their studies on structure, function and metabolic pathways etc. of host and pathogen cells provide valuable insights into the properties that distiguish the two. These differences can then be utilized by the drug designers to arrive at the perfect model of an antibiotic which, though lethal for the disease-causing microbe, leaves the host cells unharmed.

Let us understand selectivity in slightly greater detail through the example of **Acyclovir or acycloguanosine**, an acyclic purine nucleoside analogue and the most potent drug against herpes simplex virus till date. Acyclovir selectively inhibits the proliferation of herpes simplex virus (HSV), types 1 and 2 and varicella zoster virus (VZU) and has extremely low toxicity for the normal host cells. This specificity is due to the ability of these viruses to synthesize a viral thymidine kinase enzyme capable of phosphorylating acyclovir to a monophosphate (acyclo–GMP). This nucleotide form of acyclovir is subsequently converted into acyclovir triphosphate (acyclo–GTP) by cellular enzymes. Acyclo–GTP acts as a more potent inhibitor of viral DNA polymerases than of the cellular polymerases. The viral DNA polymerases incorporate acyclo–GMP into the DNA primer-template to a much greater extent than do the celluar enzymes. The viral DNA polymerase binds strongly to the acyclo–GMP–terminated template and is thereby inactivated.

On the basis of differences between cellular and HSV–specified enzymes, the high potency and selectivity of acyclovir for herpes simplex virus can be understood thus :

(i) The herpes virus specified thymidine kinase phosphorylates acyclovir ; cellular thymidine kinase does not. The normal cells contain an enzyme other than thymidine kinase, which is capable of phosphorylating acyclovir to a very small extent. (ii) The amount of acyclo–GTP formation in HSV–infected cells is generally 40–100 times greater than the amount formed in normal host cells. (iii) Viral DNA polymerases are inhibited at considerably lower concentrations of acyclo–GTP than are the cellular DNA polymerases. In other words, acyclo–GTP is a better inhibitor of HSV DNA polymerases than of cellular DNA polymerases, which results in greater degree of chain termination of the DNA template with the viral enzyme. (iv) The acyclo–GMP terminated template inhibits viral DNA polymerase 50 times more strongly than an active template.

The above-mentioned selectivities together culminate into 300–3000 fold toxicity of acyclovir to herpes viruses than to the host cells.

STRUCTURAL FEATURES OF NUCLEOSIDE ANALOGUES

Nucleoside analogues can carry modifications in their **aglycone moiety** (nucleic acid base) or their **glycone moiety** (sugar) or both.

In the double helical structure of DNA, the four bases form specific pairs only based on commands laid down by nature, as discovered by **Chargaff** and now known as **Chargaff's rules**. According to these rules, adenine always pairs with thymine or uracil (in some helical regions of RNA, althongh it normally occurs as a single strand and not a double helix) through two hydrogen bonds while guanine always pairs with cytosine through three hydrogen bonds. Based on the two categories into which the naturally occurring nucleic acid bases are divided, nucleoside analogues with modifications in the base portion can also be of two types : **purine and pyrimidine nucleoside analogues**.

Modifications in the aglycone determine the base pairing efficiency and stacking ability of the molecule, whereas modifications in the glycone determine the nucleic acid chain propagation capacity or phosphodiester bond formation ability of the analogue when the latter is utilized during replication and transcription processes of dividing cells.

The efficacy of newly developed nucleoside analogues can be screened broadly via three methods : (a) Microbiological (b) Biophysical (c) Molecular Biological.

Microbiological studies involve the screening of antiviral, antibacterial and antifungal properties of these molecules. This can be done either ***in vitro*** using **microbial and cell cultures** in which the capacity of the pathogen to proliferate in the presence and absence of the drug is monitored, or ***in vivo*** where an **animal model** infected by the pathogen is treated by the molecules under study and its response to them is observed.

Biophysical method is more commonly used by organic chemists to assess the potency of the nucleoside analogues they design and synthesize from time to time. One such method involves studies on the binding efficiency of the modified bases present in the nucleoside analogues and is also called as **Hybridization**. The underlying principle of this technique is monitoring the denaturation of a DNA deplex with increasing temperature. Naturally occurring DNA double helix denatures or uncoils within a narrow range of temperature and the temperature at which the total DNA content unzips half way through is referred to as its **melting temperature or Tm**. To study the binding efficiency of a base modified nucleoside analogue, it is chemically converted into a nucleotide and then incorported into a short sequence of nucleotides (modified oligonucleotide), which is allowed to hybridize (pairing of all the bases in the oligomer) with a complementary strand (oligonucleotide) also chemically synthesized and easily available in the market. This duplex is then subjected to an increasing range of temperature and its Tm value is obtained. For a nucleoside analogue to be efficient, its Tm value must be as near to the Tm value of natural DNA duplex as possible or may be higher. Such an analogue has better chances of getting incorporated into the nucleic acid chains during replication and transcription, thereby leading to formation of defective and nonfunctional proteins and enzymes within the pathogen.

Chain termination ability of a nucleoside analogue can be assessed by **a molecular biology technique**, where the analogue is first converted into its triphosphate form and then incubated with a DNA primer–template and DNA polymerase enzyme (devoid of its mismatch repair ability). During incubation, the enzyme synthesizes a daughter strand that may incorporate the analogue. If the latter is a chain terminator, further elongtion of the new DNA strand stops. The partial duplex is denatured at this stage and the length of the incomplete daughter strand is measured by Polyacrylamide Gel Electrophoresis (PAGE). This gives clues about the location of nucleoside analogue in the daughter strand. By comparing the location with the sequence of nucleotides in the template strand, it can also be pointed out as to which natural base does the analogue best pair with.

Though a number of nucleoside analogues have been discovered in bacteria and can thus be said to be occurring in nature, yet many of these antimetabolites have been and are being synthesized in laboratories all over the world.

NUCLEOSIDE ANTIMETABOLITES : HISTORICAL BACKGROUND

Hints regarding the efficacy of nucleoside analogues as antimicrobial agents were provided by scientists well before the greatest discovery in biology in the twentieth century–the double helical structure of DNA by **Watson** and **Crick** in 1953[4].

In 1940, **Woods**[5] and **Fildes**[6] explained the action of sulphonamides on bacteria by suggesting that they interfered with the utilization of a necessary nutrient, para-aminobenzoic acid, a process closely related with the bacterial DNA synthesis. Later George Hitchings[7,8] hypothesized that since all cells required nucleic acids, it might be possible to stop the growth of rapidly dividing cells (for example, bacteria, tumors and protozia) with antagonists of nucleic acid bases. When Ara –A (9-β-D-arabinofuranosyladenine)[9], first synthesized by ***Lee et al***[10] and later found as an antibiotic produced by *Streptomyces antibioticus*, inhibited the growth of both DNA and RNA viruses, attention was directed towards the conversion of purine and pyrimidine bases and their mimics into their nucleosides and nucleotides. This led to the development of Ara–C (9-β-D-arabinofuranosylcytosine), Ara–U (9-β-D-arabinofuranosyluridine), Ara–T (9-β-D-arabinofuranosylthymine) and Ara-AMP (9-β-D-arabinofuranosyladenine monophosphate) as antimicrobials.

Discoveries of innumerable molecules after this by the scientists of the **Wellcome Research Laboratories** have made the field of nucleoside antimetabolities replete with valuable therapeutics as well as information for the synthesis of newer and better drugs. The name of **Gertrude B. Elion**[11], a Nobel laureate, is closely associated with this research group since 1944. Acyclovir or acycloguanosine, the most effective antiviral against herpes simplex virus, owes its existence to the Wellcome Research Laboratories' scientists.

William Prusoff[12], the creator of 5-IdUrd (5-Iododexyuridine or Iodoxuridine)-the halogenated pyrimidine nucleoside analogue with antiviral properties, should not go unmentioned when we talk about nucleoside analogues.

NUCLEOSIDE ANALOGUES : OTHER APPLICATIONS

Nucleoside analogues constitute a pharmacologically diverse family that comprises, besides antiviral agents, **cytotoxic compounds** and **immunosuppressive molecules** like Cladribine, Fludarabine and Cytarabine or Ara-C (9-β-D-arabinofuranosylcytosine). Ara-C is extensively used in the treatment of acute leukemia. The mechanism of action here too is the same as that of nucleoside analogues which act as antibiotics.

The question of specificity of these nucleoside analogues towards cancer cells arises here also. A survey of research literature on chemotherapeutics, regarding this problem, reveals that selectivity of such antimetabolites for neoplastic cells probably depends on the levels of the individual anabolic and catabolic enzymes. Catabolic enzyme levels are generally much lower in tumor cells than in normal cells. In addition, mitotic rate, drug transport and metabolite pool sites influence selective toxicity.

An important enzyme that needs to be mentioned at this stage is thymidylate synthetase. This enzyme is responsible for de novo synthesis of dTMP (2–deoxythymidine monophosphate) from dUMP (2–deoxyuridine monophosphate), the only pathway for formation of dTMP for DNA in cells. Nucleoside analogues, which block the activity of this enzyme, act as potent antitumor agents. **Thomas I. Kalman**[13], of the University of Buffalo, New York, is actively engaged in the designing and development of mechanism based inhibitors of this enzyme.

The purine analogue Allopurinol (jointly developed by **Gertrude B. Elion** and **George Hitchings** of the Wellcome Research Laboratories) has exhibited excellent therapeutic effects in the cases of gout and hyperuricemia. Xanthine oxidase is the enzyme responsible for the formation of uric acid from hypoxanthine and gout is a painful condition of excessive uric acid formation followed by its deposition in the body tissues and joints. Allopurinol competitively inhibits xanthine oxidase by acting as its substrate and decreases both serum and urinary uric acid levels.

Besides their therapeutic value, nucleoside analogues find wide applications as tools in the field of molecular biology. A number of them have been developed as **universal nucleosides**[14], which can pair with any of the four naturally occurring bases, in genes, without discrimination. Universal base analogues are used to artificially produce **mutant gene libraries**. Genes from such libraries are used for protein engineering, a technique which emerged in the early eighties with the advent of site—specific mutagenesis, i.e., with the ability to introduce specific amino acid substitutions in protein sequences through mutagenic oligonucleotides[15] (very small sequences of nuclotides). Mutant proteins, resulting from this technique can be used to monitor the importance of naturally occurring proteins in living systems, or to develop novel proteins of therapeutic or nutritive value to humankind and non-existent in nature till now.

REFERENCES

1. J. Goodchild, Topics in Antibiotic Chemistry Vol. 6, ed P. G. Sammes, 133-168, Ellis Horwood Limited, England, 1982.
2. Roland K. Robins & Ganapathi R. Revankar, Antiviral Drug Development, A Multidisciplinary Approach, ed Erik De clercq & Richard T. Walker, 11-36, Plenum Press, New York and London, 1988.
3. Sarika Sinha, Richa Srivastava, Erik De Clercq & Ramendra K. Singh, *Nucleosides, Nucleotides and Nucleic Acids*, **23**, 12, 1815, 2004.
4. J. D. Watson & F. H. C. Crick, *Nature*, **171**, 737, 1953.
5. D. D. Woods, *Br. J. Exp. Pathol.*, **21**, 74, 1940.
6. P. Fildes, Lancet, 955, 1940.
7. G. H. Hitchings, *et al, J. Biol. Chem.*, **183**, 1, 1950.
8. G. H. Hitchings, G. B. Elion, E. A. Falco, P. B. Ressell, H. VanderWeff, *Ann. N. Y. Acad. Sci.* **52**, 1318, 1950.
9. F. M. Schabel, Jr., *Chemotherapy*, **13**, 321, 1968.
10. W. W. Lee, A. Benitez, L. Goodman & B. R. Baker, *J. Am. Chem. Soc.* **82**, 2648, 1960.
11. Gertrude B. Elion, *Science*, **244**, 41, 1989.
12. W. H. Prusoff, *Biochem, Biophys, Acta.*, **32**, 295, 1959.
13. Thomas I. Kalman, Zhe Nie & Ashwini Kamat, *Bioorganic & Medicinal Chemistry Letters*, **10**, 391, 2000.
14. David Loakes, *Nucleic Acids Research*, **29**, 12, 2437, 2001.
15. Mauela Zaccolo, David M. Williams, Daniel M. Brown & Ermanno Gherardi, *J. Mol. Biol.*, **255**, 589, 1996.