THE THIRTEENTH

ACHARYA JAGADISH CHANDRA BOSE MEMORIAL LECTURE

BY

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AND

DIRECTOR'S REPORT

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STATISTICAL METHODS IN NATIONAL DEVELOPMENT

The Thirteenth

Acharya Jagadish Chandra Bose Memorial Lecture

By

Prof. P. C. Mahalanobis, O.B.E., M.A., F.R.S.

I am grateful to the authorities of the Bose Institute for inviting me to give the thirteenth Jagadish Chandra Bose Memorial address this evening. I am an old pupil of Jagadish Chandra and still vividly remember him as the senior Professor of Physics in the Presidency College. In 1910-11 when I was in the third year B.Sc. class I attended his lectures on electricity and magnetism ; and when I joined the Presidency College as a member of the teaching staff in 1915 he was still the Head of the Physics Department.

In my college days Jagadish Chandra and Prafulla Chandra were two great pioneers of scientific research in India. When I was a young boy, Jagadish Chandra's work on the living and the non-living and on plant life fired my imagination with the romance and glory of scientific research. I had the privilege of knowing him personally and of having before my eyes the inspiring example of his fighting and pioneering spirit.. I take this opportunity of paying my homage to his memory.

It is, however, a matter of the deepest regret to me that the gracious Lady Bose is not with us this evening. I had the opportunity of knowing something of the service she rendered to science in an indirect way by looking after the health and comfort of Jagadish Chandra in a manner which no one else could have done. I came much closer to her during the last few years. Since 1946, I have been frequently going out of India but it was my good fortune practically every year to have come back to Calcutta at the time of her birth day in August. I made a point of seeing her on this day to ask for her blessings. When I returned to India this year she was no longer with us. I know she was eager to hear me give this address and I remember her today with love and affection.

Statistics in National Development

I wish in this lecture to give a general idea of the use of statistics in national development. The real object and justification for collecting statistical data is to use this information to make policy decisions, that is, to choose (out of two or more possible programmes of action) that particular programme which is likely to serve most effectively the purpose in view.

Statisticians, in fact, have a four-fold task in national development. Firstly, to conduct properly organised surveys for the collection, analysis, and appreciation of relevant statistical data. Secondly, on the basis of such information, to help in the choice of an efficient programme of action. Thirdly, when the plan goes into operation, to measure the progress of work and to assess the results achieved. And, finally, on the basis of such assessment, either to report that the work is proceeding as desired or to give the danger signal that the results attained are not proceeding in accordance with the plan or are not commensurate with the effort ; in which case the plan itself may have to be modified. In this way the four-step cycle would begin again.

Statistics can be used both in a strategic and in a tactical manner, that is, either to decide questions of overall economic policy and programme or for developments in specialised sectors. I shall first give examples of the tactical use of statistics of which I have some personal experience.

Applications in Agriculture

The aim of the science and practice of agriculture is to increase crop production by using better seeds and better methods of cultivation (including the use of manures). The object of conducting agricultural field experiments is to compare the yield of different varieties of, say, rice or wheat, or to compare the effect of different kinds or different quantities of manures or of different methods of cultivation. A most significant development in modern statistics took place when R. A. Fisher[1] introduced the technique of the "design of experiments" which increased the precision of field trials beyond anything that was thought possible 30 years ago. The fertility of the soil varies sometimes widely from one part to another within even a small plot of agricultural land. If the plot is divided into a number of strips and a different variety of rice is sown on each strip, it is quite possible that a really better yielding variety would sometimes give a much lower yield than an inferior variety simply because the former happened to have been sown on a strip of land in which the soil fertility was exceptionally low while the inferior variety was sown by chance on a patch of soil which was particularly fertile. Unless differences in the soil fertility can be eliminated no reliable conclusions can be drawn as to which variety has a really higher yield. After many decades of agricultural field experimentation there was a complete deadlock by about 1920, and it seemed as if further progress was not possible. It was Fisher's great contribution to show how, by a very simple change in the lay-out of the experiment, it is possible to eliminate the effect of soil differences and draw conclusions with scientific validity and high precision.* The design of experiments has been gradually extended to scientific and technological experimentation of all kinds and has added a most powerful new tool in the hands of the scientific investigation.

The much higher level of precision attended in the Fisherian design of experiments made rapid developments possible in the breeding of new and improved varieties of plants. In the case of maize in the U.S.A., amazing results have been achieved. The yield was improved to such an extent that the money value of the additional production of maize is of the order of several billions of dollars every year. With the help of the new statistical tools, fundamental genetic researches may lead to an equally startling increase in the yield of rice which would, of course, have very important repercussions on national development in India.

Applications in Industry

I shall next consider manufacturing industries. In 1924 Walter Shewhart[2] of the Bell Laboratories in the U.S.A. made another significant advance by developing what is now called "statistical quality control" (SQC). Production by modern machines called for a high degree of standardization. This in its turn requires the quality or specifications of the manufactured articles being kept within stringent limits. However, no machine (nor human being) can produce articles which are absolutely identical in shape and size. Variations are bound to occur through the influence of a multitude of chance fluctuations. It is possible, however, to attain sometimes a statistically steady state in which such chance variations remain within certain limits. Under such conditions the production is under control in the sense that the manufactured articles can be relied upon to keep within the range of permissible variations. Shewhart showed that by taking measure-

* The logic of the Fisherian design is very simple. Consider, say, a square plot of land. In pre-Fisherian experiments this plot of land would be divided into, say, 4 strips (or columns) each of which would be sown with 4 varieties of rice. In the Fisherian design each of the 4 strips is divided into 4 plots forming 4 columns and 4 rows with 16 plots in all. The varieties are then sown in such a way that each variety occurs once and only once in each column and in each row of plots. Each column (and each row) now has all 4 varieties so that the total yield of each column (or of each row) now become strictly comparable, so that soil differences, if any, can be detected and eliminated in an objective manner. Also, instead of the yield of one single strip, the yield of 4 plots for each variety is now available which makes it possible to calculate the margin of error of the estimates in a valid manner with the help of the theory of probability.

ments at suitable intervals it is possible to judge whether production is (in this sense) under control or not. This is done by plotting the observations (or measurements of manufactured articles) on what is called the Shewhart Control Chart which usually has two red lines, one at the top and the other at the bottom, at a suitable distance from the line of mean or average values. So long as the observed points lie within these control limits there is nothing to worry about. But immediately an observation goes beyond either of these limits there is an indication of a tendency for the situation to get out of control. This serves as the danger signal to look for and eliminate the disturbing factors and thus bring production back under control.

Statistical quality control is being extensively used in the U.S.A. where 3 years ago it was estimated that the use of such methods led to a saving of about 3 billion dollars per year. In India possibilities are even greater, because of the higher proportion of rejections of defective parts. To give one example, there is a good deal of waste of iron and steel because small odd size portions have to be cut and practically thrown away. Walter Shewhart, when he came to India four years ago, after visiting a large number of factories made a rough guess that with production brought under statistical control there may be a saving of 10 or 12 per cent of the iron and steel which now goes into the scrap heap. With a total steel production of something like a million ton, a 10% saving would give us an additional quantity of 100,000 tons without building any new factories. Statistical methods in commerce and industry can lead to large economies and improved production at a very low cost.

Flood Control and River Valley Projects

Flood control and river valley projects offer another example of the tactical use of statistical methods. In 1922 a very big flood occurred in North Bengal which caused a great deal of damage. An expert flood committee was appointed by Government which, after working for about a year, prepared a draft report recommending the construction, at a cost of many crores of rupees, of retarding dams or basins in North Bengal to hold up the rain water and thus give protection to the river valleys and plains. At this stage I was co-opted as a member of this committee (in my capacity as the Meteorologist in charge of the Alipore Observatory in Calcutta). On examining the question with the help of available rainfall records I found that even if all the proposed 7 retarding basins had been already in position, the level of the flood in 1922 would not have been appreciably lower. I submitted a report in which I showed that the proposed retarding basins would be of little use in preventing excessive flooding of the land. In fact, it was not necessary to hold up the water. On the contrary, the real need was to allow the water to flow away as quickly as possible. As a result of the statistical analysis the committee was convinced that the proposed retarding basins would be useless, and they accordingly recommended improving the drainage of that part of the country and other measures. Many of these recommendations were implemented at a comparatively small expense which led to a great improvement of the position, and no severe floods have occurred in this area during the last 30 years.

In 1926, there was a big flood in the Brahmani river in Orissa. An expert committee of engineers was appointed by Government which came to the conclusion that owing to the great severity of the 1926 flood a catastrophic change had occurred in the bed of the river which had risen by several feet. In order to give protection against floods, the committee recommended that the height of existing embankments should be increased and also certain new embankments should be constructed even though the cost would be heavy.

The report was referred to me for examination. A careful study of the rainfall in relation to the height of the river, however, showed that the extensive flooding of the lower portion of the Brahmani river in 1926 was almost certainly due to very heavy rainfall in the upper reaches of the river. I calculated a correlational equation based on records of rainfall and floods of previous years and with its help made an estimate of the height of the flood in 1926 which was in good agreement with the observed height. I, therefore, advised Government that there was nothing wrong with the Brahmani, and it was not necessary to waste any money by increasing the height of embankments or by constructing new embankments. Government accepted this advice in 1929 or 1930. The fact that floods in the Brahmani have not increased in frequency nor in intensity during the last 20 years or so completely corroborates the validity of the statistical findings.

At about the same time I also made a detailed study of the Mahanadi river, and I found that holding back its water in the upper reaches would be quite useful. I made some rough calculations of the intensity and distribution of rainfall in the catchment area which showed that by building dams it would be possible effectively to control floods, to produce electricity, and also to supply water for irrigation. These calculations I believe supplied a factual basis for the big river valley scheme in Orissa.

I also had occasion in 1936 to study the Burdwan-Hooghly-Howrah flushing and irrigation scheme in which the object was to build barrages to impound the water of the Damodar river for purposes of flood control, and to use the impounded water for irrigation and for flushing of the drainage area as an anti-malarial measure. I was asked by the Government of Bengal in 1936 to examine whether the expected increase in the production of rice through irrigation would be such as to justify the heavy expenditure which would have to be incurred for building the proposed dams. Unfortunately, practically no information was available about the water requirements of paddy. The problem thus required to be handled on the lines of operational research. With the help of 5 agricultural officers who possessed expert knowledge of the rice crops, hypothetical norms of rainfall requirements for paddy were constructed ; and with the help of these norms I estimated the production of rice during the previous 35 years and also what would have been the increase in production in case the barrages had been in action. I reached the conclusion that the money value of the additional yield of paddy would be sufficiently large to make the proposed scheme entirely economic. These statistical calculations probably saved the scheme in the thirties and led to the subsequent development of the great Damodar Valley project.

Statistical Sampling

I have given a number of examples in what may be called the tactical use of statistical methods in specialized sectors of national development. I shall now briefly refer to a more general method, namely, the use of statistical sampling in one form or another which has been practised probably from the beginning of human history. It is, however, only during the last 25 years or so that serious attention is being given to the use of statistical sampling on a large scale for the collection of economic and social information of all kinds, and significant developments have taken place in the design of sample surveys only during the last 10 or 15 years.

In the Indian Statistical Institute we began our work on sample surveys in 1935 in connection with an enquiry into the handloom weaving industry of Bengal. The initiation by the Indian Central Jute Committee (I. C. J. C.) of a scheme in 1937 for the improvement of the forecast of the jute crop in Bengal gave us the opportunity for the first time to develop the theory and practice of sampling methods on scientific lines. At that time detailed records were prepared every year which purported to give the area sown with jute for each cultivator in every village of (undivided) Bengal. And yet it was known that the results were in error by as much as 25% or 30% of the actual jute crop. The need for improving crop estimates led to the development of the jute census scheme. I have given an account of the work in a scientific memoir,[3] and also a non-technical description in my address on "Why Statistics?" at the Poona Session of the Indian Science Congress, in 1950. I shall, therefore. mention here only a few important points.

In the fifth year of the project a sample survey of the jute crop was conducted in a definite form over the whole of (undivided) Bengal in 1941. The method was speedy, inexpensive, and the margin of uncertainty of the provincial estimate was only about 2%. Influential opinion continued, however, to be opposed to the sampling scheme which passed through many vicissitudes. With a view to comparing the relative advantages and disadvantages of the two methods the Government of Bengal conducted directly a plot-to-plot enumeration of the jute crop of 1945 while a sample survey was simultaneously conducted by the Indian Statistical Institute on behalf of Government. The cost of the plot-to-plot enumeration was over Rs. 80 lakhs against an expenditure of Rs. 8 lakhs for a sample survey which was designed to give district estimates. (The cost would have been much less and only Rs. 4 or 5 lakhs for a provincial estimate).

The sample survey was far less expensive ; and the results, of course, could be obtained much more quickly than in a complete count. It is, however, in the matter of precision that the sample survey has the greatest advantages. It was possible to make a direct comparison of the two methods in the case of the jute crop of Bengal in 1945. The sample survey estimate, submitted to Government in September 1945, was 7,450 bales of jute while the official estimate based on the plot-to-plot enumeration was 6,450 bales. Jute being primarily a cash crop, accurate export and trade figures become available about fifteen months later. According to these figures, which became available in January 1947, the Bengal production was found to be 7,562 bales. The so-called complete enumeration was thus an under-estimation by nearly 17% while the sample survey estimate differred by less than 1%. The plot-to-plot enumeration was 10 times more expensive and yet gave entirely unreliable results.

The reason for the greater reliability of the sample survey is obvious. The staff employed in the plot-to-plot enumeration was about 33,000 against a staff of about 600 or 700 in the sample survey. In sampling work it is, therefore, possible to employ a better trained staff on higher pay and also to maintain a close supervision on their work. The primary data collected through statistical sampling are, therefore, usually of much better quality and can supply estimates of great accuracy.

I have referred only to the work in Bengal with which I am familiar. In recent years the sampling method, however, has won increasing recognition all over the world. In 1947, the United Nations established a Sub-Commission of Statistical Sampling which met once a year for 5 years and has issued 5 reports covering a very wide field.*

* The members were W. E. Deming (U.S.A.), G. Darmois (France), R. A. Fisher and F. Yates (U.K.) with P. C. Mahalanobis as Chairman.

The statistical office of the United Nations has been publishing every year a report on sample surveys of current interest, the growing bulk of which is a testimony to the rapidly increasing application of the sampling method in all parts of the world. In fact, it has now become abundantly clear that statistical sampling is the quickest, the most economical, and the most accurate method for collecting social and economic information of all kinds which exist in a diffused or scattered form. In India and other undeveloped countries where the statistical system is not highly organized, the method of statistical sampling offers practically the only possible line of advance in the immediate future.

Food Supply of India

I shall now say a few words about one or two urgent problems of our country. Consider the question of the food supply. We have to feed a population of, say, 360 millions. The question naturally arises: What is the supply of cereals required for this purpose? Are we producing enough from year to year? Unfortunately, adequate information is not available. There are large gaps in the data ; for nearly a third of the whole area of the Union of India the estimate of food supply is practically a guess work. Even in areas for which detailed information is supposed to be available its reliability is not beyond dispute.

According to official statistics, the deficit is apparently increasing, and we have to import more and more food from abroad. Is this need real, and are these imports unavoidable? That is, is the production actually falling? Or, is there a conscious or even deliberate under-estimation in order to resist the pressure of Government procurement? Areas which grow surplus food would like to keep some part of the surplus partly as an insurance against failure of crops and partly to enable a larger share being given to the local people. On the other hand, in a deficit area there is a natural desire to be on the safe side by under-estimating the production and hence over-estimating the amount required to be supplied by the Central Government. In this way, in both surplus and deficit areas, the general attitude of mind would be in favour of under-estimation of production.

Again, if there is under-estimation then any lack of efficiency in procurement would be less obvious. If production is low, the marketable surplus would be low ; and even if the machinery for procurement is efficient, the actual quantity of cereals which can be purchased must be small. So, the procurement agencies also are likely to have a bias in favour of under-estimation.

Thirdly, if there is under-estimation of production and a smaller quantity is purchased by Government then more grain would be available for sale in the black market. Profiteers in the black market (whether they are the primary growers in the villages or the dealers who operate in urban areas) would tend to encourage under-estimation of production.

There are thus strong forces in favour of under-estimation of production. The only opposing force would be the agricultural and other agencies in charge of promoting the Grow More Food Campaign who would like to show or even play up their achievements by over-estimation. As the agencies interested in the Grow More Food Campaign are far less numerous, and also as there are more powerful incentives in the black marketing of food, the balance of force would seem to be in favour of under-estimation. However, these are only conjectures. It is not possible to know the true facts as long as our food statistics are inadequate and unreliable. An important and urgent task, therefore, is to improve the food statistics of India. The only possible way in which this can be done is to organize an integrated and comprehensive sample survey of agricultural crops.

The National Sample Survey

A first step in this direction was taken by the initiation of the National Sample Survey by the Government of India in 1950. The NSS is intended to supply a continuing stream of information about social and economic conditions over the whole of the Union of India. In the first round of the field survey (which began in October, 1950) about 240 investigators visited about 1800 sample villages (selected in a suitable random manner from all over the country). In the third round (which began in July, 1951) the survey was extended to about sixty urban areas including the big four ; Calcutta, Bombay, Delhi and Madras in each of which a group of investigators would be collecting information throughout the year.

Attempts are being made from the very beginning to cover the whole of the household economy and cottage industries. Information is being collected about the production of crops and live-stock ; hand industries ; consumption of food and clothes and other items of consumer goods ; improvement of lands ; construction and maintenance of buildings ; increase of implements and means of production ; trade and transport ; professional services ; prices and wages etc. In addition, demographic and other social statistics are also being collected.

A field staff of over 400 whole time workers are posted in the sample villages and towns covering the whole country. A Statistical Branch is also working in the Indian Statistical Institute for the planning of the survey and for the processing of the material. It is intended to develop a programme in which information would be collected about important economic items twice or thrice or, if possible, four times a year. Special enquiries, *e.g.*, on literacy and health would be undertaken at longer intervals, say, once in two or three years. A little free load would also be kept for *ad hoc* enquiries at short notice. The National Sample Survey is expected gradually to supply a clear picture of household economy and also to indicate changes in the level of living in both rural and urban areas. In this way the NSS should be able to supply an integrated picture of large sectors of the national economy and of practically the whole of the consumer expenditure in India.

NATIONAL INCOME OF INDIA

I shall now consider another sphere of statistical work which is of great importance in national development. The fundamental aim of national planning is to increase the general level of living of the people. This is possible only to the extent that the total production, or more precisely, the production per head is increased. In fact, the total (or average) increase in the level of living is more or less equal to the increase in the total (or per capita) production.

National income statistics, in its broadest sense, is an attempt at preparing the accounts relating to the national economy as a whole. National income consists of the aggregate value of all goods produced and all services rendered and thus includes the value of all agricultural produce (including forest products and fish), all articles manufactured by industrial establishments or in cottage industries, all transport and communications, the value generated by trade and commerce, and also the value of professional and other services rendered to society as a whole together with the net balance of the flow of commodities and money across the boundary of the country. It is necessary, of course, to avoid double counting. For example, it is not permissible to use the value of the raw materials as well as the gross value of the manufactured articles ; it is necessary to deduct the value of the raw materials from the gross value of the manufactured product in order to get the net value added through the manufacturing process.

The total national product is used broadly in three different ways. The greater part is, of course, consumed. For example, in India, a very large part of the crops grown in any year is consumed by the agriculturists and other people in the villages. The steel produced is mostly used up with a small portion occasionally carried over in stock.

One part of the total production has to be used for repairs, replacements, and the maintenance of buildings, machinery, roads, transport equipment and facilities.

The balance after meeting current consumption and depreciation is what is called savings and is available for fresh investments, that is, for making additions to capital goods such as buildings, machinery, roads etc. It is only by making fresh investments, that is, by constructing buildings and new machines that the productive capacity can be increased from year to year.

The National Income Committee which was appointed by the Government of India in August, 1949, and which has been trying since then to lay sound foundations for this work, submitted its first report in April, 1951, and estimated that the total national income of the Union of India in 1948-49 (the first complete financial year after Partition) was about 8,700 crores. This is a rough and tentative figure which indicates that the average income was about Rs. 250 per person per year or something like Rs. 20 per person per month in that year.

Estimates like the figures given above (of either the total national income or of the average share of each person) for successive years can indicate in a broad and general way whether the economic condition of the nation as a whole is becoming more prosperous (or whether there is economic stagnation or even deterioration). In order to formulate national policy, more detailed information is needed, and it must be the constant endeavour of statisticians to supply the information in greater detail by breaking up the aggregate national income into various sectors and separate accounts.

Improvement in the Level of Living

We have seen that the rate of improvement of the level of living would depend on the new production and hence on the rate of capital investment in the country. First, what is our total or gross investment every year? Are we spending enough (in labour and materials) to repair and maintain in proper working order all our lands, buildings, machineries, roads, and transport and communications? That is, in technical language, are we using a sufficient part of the national product to set off the depreciation of our real investments and wealth. What are our net new investments (after allowing for depreciation)? That is, what are we doing for the improvement of our lands? How many new buildings, machineries, roads, transport facilities etc. are we constructing every year? These are important questions to which we do not know the answers with any degree of certainty.

Secondly, these new investments (or capital goods and equipment as they are called in technical language) would no doubt determine to a large extent the increase in the total production (and hence the increase in the level of living), but not entirely. It is also important to know how much additional production, that is, how much new goods and services we are securing from our new investments. If there are no new investments, there would be practically no new addition to the national income nor any improvement in the level of living. But whatever be the magnitude of the new investments, the increase in production would also depend on how efficient we are in using the new means of production.

In the United Kingdom, for example, the rate of new investments after the war has been colossal, namely, of the order of 20 per cent of the national product. That is, the British people have been content to consume appreciably less than four-fifths of what they produce, and after meeting depreciation charges (that is meeting the cost of repairs, replacements, and maintenance) has used such a large portion as one-fifth of the total national product in building up new means of production. The return on the new investment is believed to have been broadly of the order of 25%. That is, for each £100 used for new investments, the additions to the national product has been about £25 per year. In this way, by a great effort the British people increased during the last five or six years their national product by something like one-fourth or even a third of the income at the end of the war.

In India also the most urgent problem is to improve the level of living of the people. An important question, therefore, is how large can be the net addition to national income which we can actually attain in practice with our available resources and within the present political and social framework in India. The population is believed to be increasing at the rate of something like 1¼% per year. If the national product increases at the same rate, then the share of each individual would remain the same. The problem, therefore, is to increase the national product at a rate higher than 1¼% per year. The greater the rate of increase above this critical value of 1¼%, the greater would be the rise in the level of living.

In the draft five-year plan, the Planning Commission visualized a developmental expenditure of the order of Rs. 300 crores per year by Government. (Developmental expenditure is somewhat different from investments in the sense in which I have been using the word. However, I shall ignore the difference). If the rate of return is as high as in the U.K., namely, 25%, then the net addition to national product due to an annual investment of Rs. 300 crores is likely to be about Rs. 75 crores per year (on the assumption that the general efficiency of production is about the same in India as it is in the U.K. If it is less in India, that is, for the same investments in buildings, machinery, roads etc., if we get a smaller outturn of manufactured goods and services, then the net addition to the national product may easily be only 50 or 60 crores of rupees per year).

This is so far as the Government investment is concerned. Unfortunately we do not know what is the total investment or the maintenance and repair charges in private business. There is a suggestion that (excluding rural housing) the private sector is having fresh investments of something like Rs. 100 crores or Rs. 120 crores per year. This may add another Rs. 25 or Rs. 30 crores to the national product. At an assumed rate of total net investment of Rs. 400 crores or so we may thus expect to secure an increase of about say Rs. 100 crores or so in the national income every year.

The estimated national income for 1948-49 is Rs. 87 *abja* (or Rs. 8,700 crores). With a rise in prices, it may be, say, Rs. 9,000 crores or a little more at the present time. One per cent of the national income would be thus something between, say, Rs. 90 or Rs. 100 crores. The rate of growth of population is most probably somewhat higher, say, about 1¼%. Thus, unless we can add at least 100 or 110 crores to the national income, the level of living would either remain stationary or would actually fall. The (admittedly conjectural) reasons given above would seem to indicate that we may hope to add about Rs. 100 crores to the national income at present, and that we may be able just to maintain the per capita national income at the present level. But clearly there is little chance of a significant or rapid improvement in the near future.

The limits of investment planning on usual lines have been carefully reviewed by the Planning Commission. Apparently there is little possibility of making large investments by savings in the ordinary way. Even if the Planning Commission's figure is practically doubled and we have a total net investment of Rs. 600 or Rs. 700 crores per year, and also, if the return on the investment is about 25% (or the same as the British are now getting) then the net addition to national product would be only about Rs. 150 or Rs. 175 crores or something between 1½% and 2% of the total national income. Allowing for the growth of population at least this much of investment (Rs. 600 or Rs. 700 crores per year) would be necessary to maintain without difficulty the present per capita national income and probably also enable the level of living being slightly improved. Any significant (and visible) improvement of, say, something like 3% in the per capita national income per year would require an increase of about 4% in the aggregate which would require (at the U.K. rate of productive efficiency) a rate of investment of about 16% of our national income, or something like 1500 or 1600 crores of rupees per year.

We have, therefore, a formidable task in front of us. According to the findings of the Planning Commission, it would not be possible to make anything approaching such large investments in the near future. What then is to be done in the present situation? This is the crucial question in India today. The shortage of food supply is only one aspect of the main problem of making both ends meet in our national economy.

If we accept the findings of the Planning Commission and admit that it would not be possible to increase our national income appreciably through investments out of our own savings in the usual way within the existing social and political framework then only two possibilities are open. One is to import a great deal of capital from abroad. Is it likely that investments of the order indicated above will be available? And, if so, on what condition? These are questions which require careful thought.

The second alternative is to do what we can on our own. Fortunately in India, we have a vast amount of under-employment in the sense that a large number of people of the working age remain idle during a large part of the year. In India we also have a great deal of natural resources. It is clearly necessary to explore how the scattered but large volume of idle man-power can be harnessed to increase the national product with the help of our own material resources.

This is the supreme task of the economic organization of the country for national development. National income and operational statistics of various kinds can offer valuable guidance in deciding the economic policy. Differences of opinion, however, already exist and must arise in future about the economic programme ; and the choice would be sharper, the greater the scarcity of available resources.

It is one of the tragedies of human society that where the need is greatest, available resources (either in the form of capital goods or of relevant statistical information) are the most meagre. It is the task of the statisticians to do what they can to improve the quality and quantity of information required for national planning.

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DIRECTOR'S REPORT

(Presented to the 34th Anniversary Meeting of the Bose Institute on 30th November, 1951)

We are grateful to His Excellency Dr. H. C. Mookerjee for kindly consenting to come and preside over this anniversary meeting of the Bose Institute. Dr. Mookerjee is known to many present in this gathering as a very successful teacher of English both in Colleges and in the University, who had won the respect and affection of his pupils by his scholarship and his kindliness. Some of us have valued him as a colleague in whose agreeable company we have visited many of the Colleges of undivided Bengal and obtained some insight into the problems of higher education in provincial towns. We have followed with interest his later activities in the Constituent Assembly as Vice-President, and then as spokesman of an important minority community. It is a matter of deep gratification to all of us present here that such a highly respected citizen of the State of West Bengal has been selected to occupy the gubernatorial seat.

This institute is celebrating the 34th anniversary of its foundation on 30th November, 1917, by Acharya Jagadish Chandra Bose, principally for the purpose of carrying out his plant physiological investigations. In 1938, after the death of the founder, the Governing Body of the Bose Institute established the Acharya Jagadish Chandra Bose Memorial Lecture to be delivered at each anniversary meeting by a person of eminence, who had made substantial contributions to the advancement of knowledge in one or more subjects, preferably those in which Sir J. C. Bose himself was interested. Tonight Prof. P. C. Mahalanobis, Statistical Adviser to the Cabinet, has accepted our invitation to deliver the thirteenth Memorial Lecture and will speak on "Statistical Methods in National Development". There is a special appropriateness in Prof. Mahalanobis delivering the Memorial Lecture tonight. He succeeded Acharya Jagadish Chandra as the senior professor of Physics of the Presidency College, Calcutta. Both of them struck out original lines of investigations, which had no direct relation to the subject of the Chair occupied by them, one in Plant Physiology and the other in Statistics ; both were elected Fellows of the Royal Society of London in recognition of their contributions to their respective subjects of research. Both of them, men of vision and initiative, founded institutes for the furtherance of their special lines of investigations, *viz.*, the Bose Institute and the Indian Statistical Institute.

Obituaries

Lady Abala Bose : This evening we miss the presence of a gracious personality whose presence at these anniversary meetings, specially after the death of Acharya Jagadish Chandra, used to be made an occasion for the gathering of a large circle of friends and admirers of the Acharya and herself. I refer to the passing away of Lady Abala Bose on April 25 of this year at the ripe age of 86. Those on whom the direction of the Bose Institute devolved after the death of the Founder, will recall with gratitude the help they constantly received from Lady Bose, by her advice, by her presence at Council and Governing Body meetings, by her readiness to contact and interest important personages in the affairs of the Bose Institute. On this day last year, she was carried upstairs to dedicate the newly erected structure on the top of this lecture hall. Her last appearance at a meeting took place on March 26 this year, when in spite of her increasing weakness, she decided to attend the annual meeting of the Council of the Institute.

Lady Bose was the second daughter of the late Durgamohan Das, who, along with Sibanath Sastri, Ananda Mohan Bose, Bhagawan Chandra Bose and others, was intimately associated with the foundation of the *Sadharan Brahmo Samaj*. Owing to the loss of her mother at an early age, she had to spend a great part of her adolescent days as a boarder, mostly in the Bethune School. She and her contemporaries in the *Brahmo Samaj* were greatly influenced by the ideals of the Unitarian movement in England, and they all shared common characteristics of sobriety of deportment, high ethical standards of conduct, belief in higher education for women and in their responsibility for social service. The movement for national independence which began at that time also influenced them, and left a permanent impression on her mind. She went to Madras for medical education, but before completing her course, she got married to Acharya Jagadish Chandra Bose in February, 1887. Their fifty years of happy and eventful married life ended on November 23, 1937. It would be rare in any country to find such instances of two gifted and strong personalities with similar ideals and in many ways with complementary characters, united in matrimony and fully utilizing their inborn gifts to the service of their country and of their fellow beings. One of them was temperamental, artistic, with a romantic imagination, dreaming of the resuscitation of the achievements of ancient India as exemplified in Taxila, Nalanda, and Ajanta, interested more in putting concrete shape to his ideas rather in individuals ; the other calm and unruffled, with intuitive wisdom and human sympathy, which deepened with age and experience. While completely identifying herself with her husband's dreams and of means for their realisation, Lady Bose had her own plans for serving her countrywomen through education, which was to be cultural as well as vocational. During the latter part of their married life, the general public admired and respected Lady Bose as an ideal Indian wife, whose sole aim was to minister to the health and well-being of her gifted husband, to shield him from all the jars and disharmonies of life. But it was not so in the beginning. She was the daughter of an affluent man, unversed in the ways of household management, married to a poor professor who had taken upon himself the responsibility of repaying the debts incurred by his father in trying to start Swadeshi industries. On the advice of her father, Durgamohan Das, the newly married couple lived for the first six months by themselves in a small house in Chandernagore ; later they joined her husband's family. During the Chandernagore days she was invalidated with malaria, and it was her husband who showed his practical ability in running the household in the morning, then cross over the river Hughli to catch a train to Sealdah. Later they purchased a rowing boat with which Lady Bose used to row over to Naihati to meet her husband returning from Calcutta.

Every holiday the couple used to utilize in exploring mountainous heights, glaciers, scenes of natural beauty, of historical and archaeological interests. A full-sized camera used to accompany them in such excursions with Lady Bose serving as assistant. In his scientific activities, the period between his marriage and 1894, when as he mentions in one of his addresses, he took the decision to dedicate himself to scientific research, was one of groping. In addition to his teaching work, Acharya Jagadish Chandra was experimenting with different scientific hobbies, with photography, with the newly invented Edison phonograph, giving striking demonstrations before people invited to his home. The transition from this period of groping to that of scientific research was hastened, I believe, by Lady Bose's persuasions ; she was ambitious, as she once related, that her husband should achieve the highest scientific distinction, which at that time appeared to be the D.Sc. degree of London. Scientific papers began to appear from 1895, the first was published in the Asiatic Society's journal and the subsequent ones were communicated to the Royal Society of London and to the Electrician. The D.Sc. degree of London was soon conferred on him for a thesis embodying his investigations with short electric waves.

The first visit of the couple to England in 1896 and later to the Continent opened out a new world to Lady Bose. Her husband's lecture at the Royal Institution of London before a distinguished and appreciative audience awoke in the minds of the couple the idea of establishing an institution on similar lines in India. In her letters and diaries of that period Lady Bose dwells on this possibility. For twenty years they worked and saved towards this end ; finally, on November 30, 1917 their dreams came true with the foundation of the Bose Institute.

From 1896 to 1933 she always accompanied her husband in his many lecture tours to Europe, America, Japan and Egypt. During the visit to the International Congress of Physics held in Paris in 1900, they first met Swami Vivekananda and later Sister Nivedita. This contact aroused Acharya Jagadish Chandra's interest in the pantheistic doctrine of the universality of life phenomenon, and which found expression in some of his scientific lectures delivered during this period, on the similarity of responses in the living and the non-living. Later he selected for the Bose Institute the motto "investigations on the nascent science which includes both Life and non-Life". It was the same influence which was partly responsible for the decision to embellish their newly erected house with the help of the new school of Indian artists whose leader was Abanindranath Tagore, as well with products of indigenous crafts.

Both at home and abroad, her husband's contact with important personages in the world of science, culture, and politics was made easy by the gracious hospitality dispensed by Lady Bose ; she had mixed and found friends with many interesting personalities of her time. This chapter of her life came to an end with the passing away of Acharya Jagadish Chandra and a new one commenced which brought her in more intimate contact with problems of destitution, social injustices, and rehabilitation. The amelioration of conditions of life of the less fortunate members of her sex became the guiding passion of the remaining years of her life. To meet with increasing demands on her limited income, she had to considerably reduce her standard of living ; nobody even heard her express any regrets for the days when she with her husband lived and moved in a more gracious, social and intellectual world.

Lady Abala Bose grew up amongst people who had established the Sadharan Brahmo Samaj ; she was for some time President of the Samaj. A devout Brahmo, she built a Sadhanashram at Ariadaha for her community. As Secretary of the Brahmo Balika Sikshalaya for a number of years, it was her aim to provide in a non-sectarian religious atmosphere an all-round education for girls, to fit them to be useful citizens and future mothers. Vidyasagar was a friend of her father-in-law, Bhagawan Chandra Bose ; the institute for the training of widows founded by her was named after him as Vidyasagar Bani Bhavan. So great was her human sympathy and catholicity of mind that she provided for the inmates of the Bani Bhavan such conditions of residence that even the most orthodox of Hindu families could have no scruples in sending their widowed wards. The auxiliary organisations like the Training School, the Mahila Silpa Bhavan, the Women's Co-operative Industrial Home were started by her to provide suitable courses of training to widows and other distressed women including refugees, which would help them to earn their living and thus secure economic independence, and also imbue them with ideas of social service. She never considered such problems in the abstract ; her sympathy and practical help were always available individually to all who came to her for assistance. Besides the great work she did through the institutions founded by her, there were always instances of individuals and families being restored to health, provided with necessary training and then helped by her to secure useful employment.

Prof. N. C. Nag : The Institute has suffered another severe loss by the passing away in February last of Prof. Nagendra Chandra Nag in his 78th year of age. He served the Bose Institute as Assistant Director for 21 years, from 1918 to 1939 and during the life time of the first Director, was entrusted with the administrative work of the Institute. After his retirement he was associated with the Institute as honorary Assistant Director for five years. From the time of his appointment he was a member of the Governing Body and of the Council of the Bose Institute since its creation in 1946. Almost till the very last day, he was actively engaged in research in a laboratory fitted up in his house. His contributions ranged from glass technology, metallurgy, to plant physiology and biochemistry. The Bose Institute mourns the loss of an upright man, a loyal colleague of the Founder and a life-long well-wisher of the Institute.

Working of the Institute

Before requesting the lecturer of the evening to deliver his address, it is usual for the Director to present a short report on the working of the Institute for the past year. Tonight I shall give an account of the extension of laboratory and experiment station facilities which are in course of realisation, and then of some of the investigations which have been carried out during the past year.

The Institute carries out its investigations at three centres, *viz.*, the main laboratories, library and workshops situated at 93/1, Upper Circular Road, Calcutta, the Agricultural Experiment Station at Falta, with a temporary extension at Bamangachi ; in Darjeeling there is the Mayapuri Research Station. Investigations are carried out principally in the following Departments: Physics and Biophysics, Biochemistry and Applied Chemistry, Plant Physiology, Cytogenetics, and Microbiology. The principal sources of income of the Institute are interests received on invested funds, annual grants from the Government of India, and grants-in-aid. The total income for the current year is expected to exceed Rs. 3 lakhs.

In addition, from time to time the Institute receives non-recurring grants from the Central Government for laboratory construction, equipment of workshop and laboratory ; the amount received from this source during the last three years has amounted to Rs. 1,80,000/-; grants have also been received from the Sir J. C. Bose Trust No. 1 which has during the same period come up to Rs. 1,20,000/- of which Rs. 40,000/- received this year has been earmarked for building construction. During the next financial year the Trustees have agreed to contribute about Rs. 38,000/- for the payment of the Institute's share of the cost of purchase of about 58 bighas of Khas Mahal land at Falta, which the State Government have agreed to acquire for the Falta Experiment Station. The ratio of the State Government to Institute contribution has been fixed at one to two.

Laboratory Extension : The large hall dedicated by Lady Bose last year has been fitted up into a number of research rooms. Another two-storied block of floor area 3400 ft. will be erected soon on the South-Western corner of the Institute quadrangle which will, when complete, house the workshop and the library both of which have outgrown their present accommodations. The Central Government has been requested to supplement the donation of the Trustees with an equal grant of Rs. 40,000/- for this purpose.

Mayapuri: The potato virus investigations commenced last year in Calcutta in an air-conditioned glass house have for greater convenience been removed to Mayapuri, Darjeeling. For this purpose the Glass House in Mayapuri has been renovated and a microbiological laboratory is being fitted up. Proximity of several Government potato seed farms and their co-operation will facilitate the applied side of the investigation.

A survey is being undertaken of soil micro-organisms, specially of nitrogenfixing bacteria occurring in virgin and cultivated soils, at different altitudes in the Darjeeling district. Such a survey will be of assistance in the solution of some of agricultural and fodder-growing problems of the district.

It was mentioned on the last occasion that due to occurrence of serious land-slides in 1950 in Darjeeling, our scheme for setting up of a cosmic ray laboratory was kept in abeyance. Arrangement has been made to send a team of cosmic ray workers to Darjeeling next Spring. The investigations we are starting in Darjeeling are of an exploratory nature and for putting them on a permanent footing additional grants will be necessary from authorities interested in these lines of investigations. Our present income is being fully utilized for the maintenance and extension of our work in Calcutta and Falta. Much of our time and efforts were spent last year in equipment of the new laboratory and in the construction of new apparatus and the testing of new techniques.

RESEARCH ACTIVITIES

Physics: Investigations are confined to the study of cosmic rays, nuclear reactions, construction of a neutron generator, and of a pulse generator of ultrasonic radiation. In connection with the investigations of mutagenic action of radiations we are using X-rays, ultraviolet and ultrasonic radiations. One of the problems before us is the devising of measuring instruments by which the absorption of the different kinds of radiation can be measured in comparable units.

We are studying the time distribution of cosmic ray intensity and its correlation with solar and geophysical phenomena, by means of a large pressure ionisation chamber. Similarly, the association of bursts in large air showers and the relative proportion of penetrating and soft radiations in the latter at different altitudes are being investigated by means of a combination of a counter telescope and a small pressure ionisation chamber. Showers and bursts produced by the interaction of penetrating cosmic ray particles with atomic nuclei will be studied by means of a large rectangular Wilson Chamber under construction. Similarly, another small Wilson Chamber for the study of the masses and mean lives of heavy and light mesons is under construction. An electromagnet consuming about 25 kw. of energy and producing a magnetic field of 6 to 8 thousand gauss is being constructed for use with the small Wilson Chamber.

In co-operation with the Regional Meteorological Directorate we have made preliminary trials in sending up packets of nuclear emulsion plates up to 40,000 ft. altitudes in pilot balloons. There was an interruption of these flights during the monsoon ; it will be soon resumed. We are grateful to the Directorate for their help and willing co-operation.

For nuclear investigations we are studying the efficiency and reliability of a scientillation counters made in the Institute for detection of charged particles, neutrons, and photons. Use of radioactive phosphorus and carbon 14 as tracer in plant physiological investigations is being developed.

Physicochemical methods for the detection, isolation and examinations of the structure of large molecules of biological origin like viruses, enzymes, proteins are being developed including electrophoresis and chromatographic methods.

One of the problems taken up in the Institute is to follow up systematically the process of retting of bast fibres like jute, coconut, by the enzymes secreted by retting bacteria and fungi. Identification of enzymes occurring in plant organs will be facilitated by the application of paper chromotographic method.

In *Microbiology* we are continuing our survey of antibiotic producing micro-organisms from soils obtained from different regions of Bengal, Bihar, Orissa and Madras. Five potent strains of micro-organisms have been selected for further study, with special reference to their biochemical activities, chemical purification and isolation of antibiotic principles. Some of the strains are being subject to the mutagenic action of ultraviolet radiation with a view to evolving of more potent ones. The irradiated strains are being cultured and examined for the presence of new mutants. The inhibitory effects of three of these antibiotic substances against six strains each of *Rhizobium* and *Azotobacter* are being tested in the laboratory as a preliminary to the field study ef antagonism between different types of soil micro-organisms. Investigations on the effect of presowing treatment of seeds of six major pulses of this country with suitable strains of the nodule producing organisms are being carried out. The results of the first year's experiments indicate the beneficial effect of bacteriasation on Indian legumes. They are being repeated this year.

Antibiotics and tadpole metamorphosis: The growth-promoting effects of antibiotic substances mixed with feed stuff have been reported in the case of pigs and poultries, but not in the case of ruminants. In course of investigations carried out to find out whether certain vitamins or hormones in the feed stuff were responsible for caste differentiation between workers and queens in ants, it was found that mixing different concentrations of penicillin in the feed stuff given to workers had growth-retarding effect. The effect of penicillin on the growth and metamorphosis of tadpoles was next investigated. It had been noticed previously that the metamorphosis of tadpole to frog was retarded by starvation. But on restoration of the tadpoles to a normal diet, restored their capacity for metamorphosis. On keeping the tadpoles in very dilute solutions of penicillin a similar retardation of metamorphosis was observed. Further, unlike the effect of starvation which retarded both growth and metamorphosis, in the case of tadpoles grown in water containing penicillin but with full component of feed stuff there was some growth but no metamorphosis. The tadpoles have remained in this condition for the last six months. The investigation is being continued ; no interpretation of the observed effect is possible at this stage.

Mutagenic action of radiations: We are continuing our investigations on the mutagenic effect of x-radiation on jute, oilseeds, and cotton. With jute, as previously reported, three new mutants appear to have been stabilized, *viz.*, a tall mutant, a multi-stemmed one, and an early flowering one ; with Sesamum some interesting effects have been observed in the XI generation, *viz.*, the production of multi-stemmed plants with a corresponding increase in the number of seed pods per plant. If this strain becomes stabilized, a new mutant will be evolved with a considerable increase in oilseed production per unit area.

We are making a comparative study of the cytological effects of different radiations like X-ray, neutron and ultrasonic radiations, as well as of chemicals on different plant organs. While the mutagenic action of X-rays on certain economic plants has been definitely established, other radiations have produced cytological effects but their mutagenic properties have not been established in our Institute. The cytological and mutagenic actions of different chemicals including penicillin, polyporin are being studied.

Plant Physiology: In plant physiology we are continuing our investigations on the isolation, purification and structure determination of the plant hormone responsible for the transmission of excitation in Mimosa, and for the production of mechanical response of closure of the leaves, and the bending of the pulvini. Our research fellow in Biochemistry has spent a very fruitful year in the laboratories of Prof. Kuhn in Heidelberg, and of Prof. Hesse in Freiburg, in studying natural and synthetic plant hormones. Owing to the highly oxidisable nature of the irritability hormones of Mimosa and the difficulty of standardising its concentration by physiological tests, it has not yet been possible to purify it completely. Preliminary observations make it appear probable that the hormone which controls the pulsatory movement of the leaflets of *Desmodium gyrans* is similar to or identical with the irritability hormone of Mimosa. This observation is interesting in view of the recent findings that acetyl choline, a chemical substance responsible for transmission of excitation in animal nerves and of the resulting contraction of the attached muscles is also responsible for the production of rhythmic contraction in isolated animal hearts. These are instances of the principle, that in the world of animate nature, the biochemical processes underlying transmission of excitation, tissue contraction, carbohydrate metabolism etc. as well as the structural units through which such activities are performed, are limited in number ; and that both in animals and plants they are either identical or analogous in character. I hope it will be possible at the next anniversary meeting for me to say something more on these elementary building blocks of nature which underlie organic design.