Science, Society & Peace

(15 essays by Damodar Dharmanand Kosambi)

Professor D. D, Kosambi was one of the best-known Scientists of our country, endowed with a truly renaissance versatility. Shunning the limelight of publicity, he made, outstanding contributions in various fields of knowledge, which included Mathematics, Statistics, Numismatics, Indology, History as well as contemporary social problems.

He was on of the few great Indians who had grasped the nature of twentieth century science and technology and its implications for humanity. He showed genuine awareness of the interaction between and social processes particularly in the context of the under-developed countries. His approach to science and its application was always an integrated one and not purely technical.

He devoted a great deal of his time to the Peace Movement and the campaign against nuclear weapons.

This collection of 15 essays brings together for the first time Prof, Kosambi's contributions on science, society & peace. It is relevant today in that it deals with many of the themes, which have come to the forefront of discussion in last few years. Some of the questions explored are: What is science? Do social systems make any difference to the nature of science and its progress? What should be the appropriate direction of development of science and technology in under-developed countries? Why is research on solar energy rather than atomic energy more important to India? What is the real character of the nuclear danger? How should we judge the greatness of a scientist and his work from the perspective of the future of mankind?

The Academy of Political and Social Studies, Pune is proud to bring out its first publication consisting of 15 essays on 'Science, Society and Peace,' written by the late renowned scientist Professor D. D. Kosambi. These essays contributed to different periodicals over a period of more than two decades do not exhaust the entire list of his writings, in which as a socially conscious citizen of the world and of his own country Prof. Kosambi showed, acute awareness of the socio-political problems of his day. In this International Year of Peace when issues arising out of the development of science and technology and the dangers of nuclear holocaust are being widely discussed all over the world, readers will be struck by the foresight that this well-known mathematician showed several years ago.

Even a quick recollection of his achievements in various fields will go to show what this remarkable scientist gave to the world before he passed away in his sleep at the early age of 58, on 29th June, 1966.

Kosambi's formula for chromosome distance occupies a significant place in classical genetics. His painstaking research on coins makes the numismatics of hoards into an exact science. A large collection of microliths and megaliths with rock-engravings, as also the discovery of *Brahmi* inscription at Karle form useful contributions to archaeology. His editions of the poetry of Bhartrihari and of the oldest known Sanskrit anthology - Subhashitara tnakosha - are acknowledged land-marks in Indian text-criticism' Even those who disagree with the underlying philosophy in his works, admit that Prof. Kosambi's research papers and books on the history of India, have broken new ground for further valuable research on the unique characteristics of the evolution of the social structure of India.

Profound insight combined with an acute sense of detail, complete grasp of the material under study, and creative use of the dialectical materialist method, enabled him to raise significant new questions and to offer original answers.

It would have been difficult to bring out this publication had it not been for the invaluable co-operation of our friend Shri. R.P. Nene, who was one of Prof. Kosambi's closest junior friends for many years and accompanied him frequently on his field trips for studies in historical research. We know that he would feel offended if we were to thank him, but we know of no other way of expressing our gratitude.

Our thanks are due to Shri. H.Y. Shinde and the workers of Pravada Printers for printing the book in time on the occasion of the 20th death anniversary of Prof. Kosambi.

We hope that all those who are interested in the topics covered in the essays and especially the activists in various people's science and peace movements will welcome this publication and do 911 they can for its wide distribution.

" Only in Science planned for the benefit of all mankind, not for bacteriological, atomic, psychological or other mass warfare, can the scientist be really free. " D. D. Kosambi

Other Books by D. D. Kosambi

1. An Introduction to the Study of Indian History (1956)
2. Exasperating Essays: Exercises in the dialectical method (1957)
3. Myth & Reality: Studies in the formation of Indian Culture (1962)
4. The Culture & Civilization of Ancient India in Historical outline (1965)
5. Indian Numismatics (1981)
6. D. D. Kosambi on History & Society: Problems of Interpretation (1985)

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1.STEPS IN SCIENCE

1. Why Science?

The question ‘Why solve problems?’ is psychological. It is as necessary for some of us as breathing. Why scientific problems, not theology, or literary effort, or some form of artistic expression? Many practicing scientists never work the answer out - consciously. A few centuries ago, questions of religious philosophy and theology ruled supreme for the intelligentsia of many ·countries. Those lands where the leading intellectuals persisted in these speculations remained ignorant, backward and were progressively enslaved (like India) in spite of a millennial culture. No advance was possible out of this decay without a modern technique of production, towards which the intellectual’s main contribution was through science. There is a deeper relationship: Science is the cognition of necessity; freedom is the recognition of necessity. Science is also the history of science. What is essential is absorbed into the general body of human knowledge, to become technique. No scientist doubts Newton’s towering achievement; virtually no scientist ever reads Newton’s original writings. A good undergraduate commands decidedly more physics and mathematics than was known to Newton, but which could not have developed without Newton’s researches. This cumulative effect links science to the technology of mechanized production (where machines save immense labour by accumulating previous labour) to give science its matchless social power, in contrast to art and literature with their direct personal appeal. Archimedes, Newton, Gauss form a chain wherein each link is connected in some way to the preceding; the discoveries of the later would not have been possible without the earlier. Shakespeare does not imply the pre-existence of Aeschylus or of Kalidasa; each of these three has an independent status. For that very reason, drama has advanced far less from the Greeks to the present day than has mathematics or science in general. The earliest statues of Egypt and Greece, the first known Chinese bronzes, show a technical mastery of the material and of art forms that make them masterpieces even now, though the artists remain unknown; but the technique is not linked to production as such, hence not cumulative. The artist therefore survives if and only if his name remains attached to some work that people of later ages can appreciate. The scientist, even when his name be forgotten, has only to make some original contribution, however small~ to be able to say with more truth than the poet, ‘I shall not wholly die, the greater part of me will escape Libitina.’ The most bitter theological questions were

argued out with the sword; for science, we have the pragmatic test, experiment, which is more civilized except when some well-paid pseudo-scientist wishes to 'experiment' with thermonuclear weapons or bacterial warfare.

2. Natural philosophy

I went to school and college in the USA. It was obligatory to learn several European languages in school and college. The libraries were unquestionably the best in the world for accessibility and range of books. Alexander von Humboldt's *Cosmos* surveyed the whole universe known to the nineteenth century, from the surface of the earth to those mysterious prawn-shaped figures visible through the most powerful telescopes, the spiral nebulae. The Einstein theory, arousing passions of theological intensity, had just been regarded as proved, and offered new insight into the structure of space and time. Innumerable outlines made it easy to learn something about every branch of science. Freud had taught men to take an honest look at their own minds. H. G. Wells showed through his *Outline of History* how much the professional annalistic historian had to learn. The inspiring lives of Pasteur and Claude Bernard proved that man could gain new freedom from disease through the laboratory; the deadliest poison became a tool for the saving of life through investigation of the body's functions. Such were the real *rishis* and *bodhisattvas* of modern times, the sages whose social achievement added to man's stature. This contrasted with the supposed individual perfection of mythical Indian sages, expressed in incomprehensible language and fantastically interpreted by commentators. It is fatally easy to preach about the spiritual superiority of India to the materialistic West; the ability to replace incomprehensible Sanskrit words by still longer and equally meaningless English terms can make a prosperous career.

Engineering is based upon physics and chemistry, which are qualified as 'exact sciences' precisely because they admitted a mathematical basis. No other discipline unlocked the door to the atom or to the movement of celestial bodies equally well, as mathematics did. Aptitude granted, mathematical research needed the least financial resources of any science. However, I chose mathematics because I could not resist its fascination. Mathematical results possess clarity and give an intellectual satisfaction above any others. They have absolute validity in their own domain, due to the rigorous logical process involved, independent of experimental verification upon which applications to the exact sciences must depend. Mathematics was the language of nature, *seienlinrum clavis et porta* as Roger Bacon put it.

Unfortunately, not every kind of mathematics unlocks every door to nature's secrets. For some twenty years, my main work lay in tensor analysis and "path geometry" (my own term). Though fundamental for the theory of relativity, the discipline is of interest only to a few specialists. In 1949, Einstein pointed out to me during one of several long and highly involved private technical discussions that certain beautifully formulated theories of his would mean that the whole universe consisted of no more than two charged particles. Then he added with a rueful smile, 'Perhaps I have been working on the wrong lines, and nature does not obey differential equations after all.' If a scientist of his rank could face the possibility that his entire life work might have to be discarded, could I insist that the theorems whose inner beauty brought me so much pleasure after heavy toil must he of profound significance in natural philosophy? Fashions change quickly in physics where theory is so rapidly outstripped by experiment. It seemed and still seems to me that non-associative linear algebras and Markov chains would remove many of the physicists' theoretical difficulties; tire experimenters are satisfied. with abandoning the principle of parity. The 'red shift' of distant stars will perhaps be explained one day as due to the absorption of energy when light travels at cosmic distances through extremely tenuous matter, not as evidence for an expanding universe. Such speculations are of no use unless tallied in mathematical detail with observed data.

3. Chance and certainty

Borderline phenomena of classical physics illustrate the inexhaustibility of the properties of matter. Ice, according to the textbooks, melts and water freezes at zero degrees Centigrade. But when carefully purified samples of water are slowly cooled and the ice slowly melted again, a considerable gap is found between the melting and freezing points. Fundamental particles that make up the atom and its nucleus show another type of aberrant behaviour. An electron can cross a potential barrier, as if a stone were of itself to roll uphill against gravity, and down, the other side. Even the observation of isolated particles becomes difficult, for the very act of observation means some interaction and effect upon the observable. The certainty of classical physics comes only when many fundamental particles are organized into higher units with clear patterns. In the same way, individual molecules of water may move in any direction with almost any speed, but the river as a whole shows directed motion in spite of eddies. So also for aggregates of living matter. In human society, the net behaviour of the group smoothes out the vagaries of individual action.

The mathematical analysis best suited for handling such aggregates is the theory of probability, the estimation of chances. Variation is as important a characteristic of the collective as the mean value. Prediction can only be made to within a certain probability, which sounds like the language of the racecourse. But when the chances of a mistake amount to one in a million, most people take the effect as certain. The level of significance desired may be personal matter. For example, there is a chance of a letter being lost in the mail; whether or not we register or insure it depends upon our estimate of the risk involved, and the expectation of loss. Thus, modern statistical method can be an excellent guide to action. It extends the assurance of exact science to biological and social sciences. Though no man can say when death will come to him, as it certainly must to all men, it is fairly easy to predict within a reasonable margin of error about how many men out of a large group will die after a set number of years. That is why life insurance manages to be a highly paying business, without recourse to astrology. It is further possible to say how the occupation and living conditions affect longevity. The man who has to work in a lead mine (without special protection) has his expectation of life reduced by a predictable number of years, more surely than those shot at by lead bullets on the battlefield.

The method of proof for deductions based upon probability differ radically from those of pure mathematics. Conclusions cannot be 'true or false' without qualification, when the variation inherent in the trials is assessed. The standard method is to set up a 'null hypothesis', take the observed results as due to purely random independent variation. The theory suitably applied (and the application needs profound grasp) then gives one of two conclusions: that the numerical observations are compatible with the hypothesis, or not. But either conclusion would be true only with a certain calculable probability, which tells us about how often we would go wrong in action. The trick is to set up the experiment in such a way that the desired action may be taken if the null hypothesis is contradicted; for, the incompatibility implies falsehood whereas compatibility need not imply truth.

This leads to difficulties in dealing with phenomena where the experimenter's will; to believe is stronger than his common sense. Parapsychologists test *ESP*, 'extra-sensory perception' (such as telepathy) by having two people match cards at a distance. The effect is so faint and irregular as to call for recondite statistical tests, which apply on the null hypothesis that the matching could have been obtained by mere chance. The tests then show that the chances are very small, wherefore the parapsychologists claim victory. The null-hypothesis is contradicted, but the reason given is not necessarily true. Shuffling the cards does not randomize them efficiently, i.e. pure chance is not fully effective. There are excellent statistical tests for such randomization, and it was shown by my own experiments that the kind of shuffling practiced for *ESP* is inefficient when judged by the same kind of statistics that is applied to card matching. Cards originally next to each other tend too often to stick together. Claims for ESP would be more convincing if one produced supplementary evidence (say matching encephalograms for sender and receiver) for a physical mechanism of transmission. Some regard the effect as beyond the normal sensation, transcendental, not accessible to material analysis. In that case, there is no logic in any Laboratory tests; the statistical 'proof' becomes mere ritual.

One of my theoretical papers deals with probability and statistics in infinitely many dimensions. There has been no effective use, because the attempts at getting a special electronic calculating machine to translate this theory into practice failed. No one with the requisite resources has yet felt the need. On the other hand, a paper on genetics was unexpectedly successful. Professional geneticists use it for all kinds of investigations, such as heredity in house mice. It seems to have given a new lease of life to genetical theories which I, personally, should like to see revised; so that I am accused at times of not appreciating my own formula. It would have been pleasant to see the formula applied to the increase of food production; but the pure scientists of a country, which grows the world's greatest food surpluses and destroys them to keep grain prices high in a hungry world sneer at 'clever gardening'. There is some difference of opinion here as regards the proper relation of theory to practice.

4. Ancient Indian culture

To teach myself statistics, I had to take up some practical problems from the very beginning. One such was the study of examination marks of students. It turned out that even the easiest of examinations in India (the first-year college examination) was based on a standard that differed from that of the instruction, if in twenty-five years no student of the 90% or more who passed could score more than 82% overall while the professors who taught and examined had scored much less in their own time. Improvement of the system (whether in examination or instruction) was out of the question in a country where the teaching profession is the wastebasket of all others, and the medium of higher instruction is still a foreign language.

A more fruitful problem was the statistical study of punch marked coins. It turned out that the apparently crude bits of 'shroff-marked' silver were coins as carefully weighed as modern machine-minted rupees. The effect of circulation on any metal currency is obviously to decrease the average weight in proportion to the time and to increase the variation in weight. The theory of this 'homogeneous random process' is well known, but its applications need careful work on whole *groups* of coins. Moreover, it is necessary that the history of the coins be closed in antiquity, at one time; this means deposit in a well-preserved hoard. The main groups of punch-marked coins in the larger Taxila Hoard could be arranged in definite chronological order, the oldest groups being the lightest in average weight. There seems to have been a fairly regular system of checking the coins in antiquity. As control, I personally weighed over 7,000 modern coins (taken from circulation) one by one, on slow analytic balances. It was then possible to lay the foundations of numismatics as a science, as contrasted to a branch of epigraphy and archaeology. Taxilan economy of the period was beautifully revealed by the coins though the coins bore no legends.

Arranging coin-groups in order of time led naturally to the question: Who struck these coins? The hoard was dated to about ten years after Alexander's death. But who were the Indian kings, if any, who left the marks on the coins? The written sources display a shocking discordance. The *Puranas*, Buddhist and Jain records often give different names for the same king. Study of the records meant some mastery of Sanskrit, of which I had absorbed a little through the pores without regular study. Other preoccupations made it impossible to spend as much time as the average student on the classical idiom. So, the same method was adopted as for study of statistics: to take up a specific work, of which the simplest was Bhartrhari's epigrams *(Subhasitas).* The supposed philosophy of Bharatrhari, as glorified by the commentators, was at variance with his poetry of frustration and escape. By pointing this out in an essay, which made every Sanskritist who read it shudder, I had fallen into Indology, as it were, through the roof.

There was one defect in the essay, namely that the existence and the text of Bhartrhari were both rather uncertain. This meant text-criticism, which ought to have been completed in a few months, as the entire work supposedly contains no more than 300 stanzas. Study of about 400 manuscripts showed numerous versions with characteristically different stanzas, as well as divergent readings in the common verses. It took two and a half years of steady collation work to realize that I should not have undertaken such a task; but abandoning it then would mean complete loss of the heavy labour, which could yield nothing to whoever came after me. It took some five years to edit Bhartrhari, with results that have received professional approval. The methods did not apply when the oldest known anthology of classical Sanskrit verse, composed about 1100 A. D. under the Pala dynasty was edited (with a very able collaborator) from atrocious photographs of two manuscripts, one in Tibet, and the other - most corrupt - in Nepal. My judgment of the class character of Sanskrit literature has not become less harsh, but I can at least claim to have rescued over fifty poets from the total oblivion to which lovers of Sanskrit had consigned them, not to speak of adding to our meagre knowledge of many others.

All this gave a certain grasp of Sanskrit, but hardly of ancient Indian history; the necessary documents simply did not exist. My countrymen eked out doubtful sources with a powerful imagination and what L. Renou has called 'logique imperturbable'. One reads of the revival of nationalism and Hinduism under Chandragupta II, of whom nothing is known with certainty. Indian nationalism is a phenomenon of the bourgeois age, not to be imagined before the development of provincial languages (long after the Guptas) under common markets. Our present-day clashes between linguistic groups are an index to the development of local bourgeoisies in the various states. Hinduism came into existence after the Mohammedan invasion. Clearly, one of two positions had to be taken. India has no history at all, or some better definition of history was needed. The latter I derived from the study of Karl Marx, who himself expressed the former view History is the development in chronological order of successive changes in the means and relations of production. This definition will have to be abandoned for a better one if we cross the threshold to a radically new and better form of society. Then and only then will human history really begin, but till that time my definition will have to serve. We have, therefore an Indian history without the episodes that fill the history books of other countries. But where were the relevant new sources? Granted that the plough is more important than a list of kings, when and where was it first introduced? What class took the surplus produced thereby? Archaeology provided some data, but I could get a great deal more from the peasants. Fieldwork in philology and social anthropology had to be combined with archaeology in the field as distinguished from the site archaeology of a 'dig'. Our villagers, low-caste nomads and tribal minorities live at a more primitive stage than the city people or even than the brahmins who wrote the Puranas. Their cults, when not masked by brahmin identification with Sanskritized deities, go back to pre-history, just as Romans at their sacrifices used stone axes and bronze knives. Tracing a local god through village tradition gives a priceless clue to ancient migrations, primitive tracks, early trade routes and the merger of cattle-breeding tribesmen with food gatherers, which led to firm agricultural settlement. The technique of observation has to be developed afresh for every province in India The conclusions have had a mixed reception because of reference to Marx, which automatically classifies them as dangerous political agitation in the eyes of many. At the same time official Marxists look with suspicion upon the work of an outsider.

The method continues to give new and useful results. Experts say that my collection of microliths is unique, not only in range of sites but in containing the first known pierced specimens. A totally unsuspected megalithic culture came to light in this year's fieldwork. It fell to my lot to discover, read and publish a Brahmi inscription in plain sight at Karle caves, which had passed unnoticed though some 50,000 people visit the place every year. My suggestion for using Malshet pass should give Maharashtra a badly needed key road from Bombay to Ahmednagar, and save a few million rupees that would have been wasted by a projected spectacular funicular railway down Naneghat.

5. Social aspects

The greatest obstacles to research in any backward, under-developed country are often those needlessly created by the scientist's or scholar's fellow citizens. Grit may be essential in some difficult investigation, but the paying commodity is soft soap. The meretricious ability to please the right people, a convincing pose, masterly charlatanism and a clever press agent are indispensable for success. The Byzantine emperor Nikephoros Phokas assured himself of ample notice from superficial observers, at someone else's expense, by setting up in his own name at a strategic site in the Roman Forum, a column stolen from some grandiose temple. Many of our eminent intellectuals have mastered this technique.

There is little point in discussing personal experience of the scum that naturally floats to the top in a stagnant class. The deep question is of fundamental relationship between the great discoverers and their social environment. Conservatives take history as the personal achievement of great men, especially the history of science. The Marxist assertion is that the great man; is he who finds some way to fulfill a crying social need of his times. Thus, B. Hessen explained Newton's work in terms of the technical and economic necessities of his class, time and place. The thesis was successful enough to be noticed and contested by a distinguished authority on 17th century European history, Sir George Clark. Clark's knowledge of the source is unquestionably greater than Hessen's; but the refutation manages to overreach the argument. According to Clark, 'the scientific movement was set going' by 'six interpenetrating but independent impulses' from outside and 'some of its results percolated down into practice and were applied'. The external impulses were 'from economic life, from war, from medicine, from the arts, and from religion. What is left then of the independence of science? The sixth impulse was from the 'disinterested desire to know'. So far as I know, all six impulses applied from the very earliest civilisations of Mesopotamia, Egypt, China, and probably the Indus Valley, without producing what we recognize as 'science' from, say, the time of Galileo, What was the essentially different factor? The Marxist answer would be: 'the rise of the proto-bourgeoisie in Europe'. No Marxist would claim that science can be independent of the social system within which the scientist must function.

Much the same treatment may be given to literature. Disregarding oversimplification, can one say that Shakespeare's plays manifest the rise of the Elizabethan proto-bourgeoisie, when the said dramas are full of kings, lords and princes? The answer is yes. Compare Hamlet or Richard the Third with the leading characters in the *Chanson de Roland*. Not only Pistol, Nym and Bardolph but the fattest Shakespearean parts like Shylock and Falstaff are difficult to visualise in feudal literature. The characters in those plays have a 'modern' psychology, which accounts for their appeal to the succeeding bourgeoisie, and hence the survival value of the dramas themselves. Troilus and Cressida are not feudal characters any more than they are Homeric; Newton's Latin prose and archaic geometrical proofs in the *Principia* make that work unreadable, but do not make it Roman or Greek science.

Talking with Indian peasants gives a grim view of modern India, and of the service science can render to any society based upon the profit motive. The demoralisation of the poor and middle peasants (the vast majority) is explained by the miserable diet on which they have to subsist, year in and year out, generation after generation, with no hope of better. The passive, unresisting stratum thus created may provide the foundation for a dictatorship that could be evoked by the naked greed of kulak and petty-bourgeois, the cynical grab of Big Money, facile opportunism of pliable intellectuals and the leaden foot of bureaucracy never remarkable for honesty and efficiency. Surely, the problem of a better food supply is crucial, not only for attaining the socialism which is announced as India's goal, but even to preserve what democracy the country Possesses. But

what can the scientist do?

India, the experts tell us, is overpopulated and will remain poor unless birth control and population planning is introduced. But surely, overpopulation can only be with respect to the available food supply. Availability depends upon production, transport, and the system of distribution - here under private control. What is the total amount of food produced? We have theological quarrels between two schools of statisticians, but no reliable estimate of how much is actually grown, and what proportion thereof escapes vermin - including middlemen and profiteers - to reach the consumer. If shopkeepers can and do raise prices without effective control, what does a rise in the national income mean? Is it the scarcity of grain or of purchasing power' A great deal is said about superstitious common people who must be educated before birth control becomes effective. No superstition which runs strongly counter to their fundamental economic interests continues for long to grip the 'common people'. Children are the sole means of support for those among the common people who manage to reach helpless old age. The futility of numerical 'planning' for the population, when nothing is done to ensure that even the able-bodied will have a decent level of existence, is obvious to any one but a born expert. It is not that our poverty is due to overpopulation, but rather that the overpopulation is due to poverty. Convince the common people that they will be fed and looked after even when they have no children, and birth control will immediately become popular.

Let me give two small examples of scientific effort, which could easily have been turned to better account. Considerable funds will be devoted during the Third plan to research on the uses of bagasse (sugarcane pulp). At present, it is used as fuel, and the ashes as fertilizer, whereas paper and many other things could be made from it. But are the other uses (quite well known) the best in the present state of Indian economy? The extra money to be spent on fuel, not to speak of difficulties in getting fuel, would increase the already high cost of sugar manufacture; new factories for byproducts mean considerable foreign exchange for the machinery and for the 'experts'. But Hungarian scientists fermented the bagasse in closed vats. The gas given off can be burned, so that the fuel value is not reduced; the sludge makes excellent fertilizer for the fields, without any Further treatment; this saves money on chemical fertilizers and improves the soil. The scheme has apparently been pushed into the background. Again the proper height of a dam is important in order to reduce the outlay to minimum, without the risk of running dry more than (say) once in twenty years. The problem is statistical, based upon the, rainfall and runoff data where both exist. The principles I suggested were adopted by the Planning Commission, though not as emanating from me. Neither the engineers nor the Planning Commission would consider a more important suggestion, namely that many cheap small dams should be located by plan and built from local materials with local labour. Monsoon water: would be conserved and two or three crops raised annually on good soil that now yields only one. The only country where I have seen innumerable small darns spring up during the last five years is China, which has not failed to construct giant dams wherever necessary. However, it is futile to speak - even from my personal observations in the field of the exhilarating achievements, social and material, of the Chinese since liberation. Here, the obstacle is not ignorance, but private ownership and lack of co-operation.

This country needs every form of power available, but is too poor to throw money away on costly fads like atomic energy merely because they look modern. A really paying development will be of solar energy. The advanced countries have not so much sunlight as we do, hence care less for the development. The problem lies deeper than is imagined. The reforestation indispensable for good agriculture will not be possible without fuel to replace firewood and charcoal. Coal mining does not suffice even for industry; fuel oil has to be imported. An efficient solar cooker would be the answer; such cookers exist and have been used abroad. The one produced in India was hopelessly inefficient (in spite of the many Indian physicists of international

reputation). Tremendous publicity and a faked demonstration made the gullible public buy just enough useless 'cookers' for a quick profit to the manufacturer,

In one matter, it was necessary to speak out though it meant considerable damage to finances, health and research. Atomic war and the testing of nuclear weapons must stop. A flimsy 'Indian Report' on the effects of atomic relation shows our moral and scientific bankruptcy by ignoring the extensive data compiled since 1915 in the one country whish has had the most painful experience of atomic radiation applied to human beings - Japan. The real danger is not death, which is a release for most Indians, but genetic damage to all humanity. We know what radiation does to heredity in the banana-fly *Drosophila melanogaster*, with its four chromosomes and life cycle of eleven days. A good deal was found out in the USA about what happens to laboratory mice. What little has been released for publication is enough to terrify. Man is as much more complicated than a mouse as the mouse than the fruit fly. Humans take a proportionately longer time to breed and to reach maturity, giving fuller scope for genetic derangements to develop. It may take some twenty generations to find out just what these derangements amount to. By then they will have been bred into many millions of human beings, not as a disease but incurably as a set of hereditary characters. Mankind cannot afford to gamble with its own future in this way, whether, that future lies in the hands of communists or not.

2. SCIENCE AND FREEDOM

In 1949, I saw that American scientists and intellectuals were greatly worried about the question of scientific freedom, meaning thereby freedom for the scientist to do what he liked while being paid by big business, war departments, or universities whose funds tended to come more and more from one or the other source. These gentlemen, living in a society where he who pays the piper insists upon calling the tune, did not seem to realize that science was no longer 'independent' as in the days when modern machine production was still expanding at the lower stage of technical development, and the scientist who made the most essential discoveries was looked upon as a harmless individual toying with bits of wire, chemicals, perhaps collecting odd specimens in out of the many places. The scientist now is part of a far more closely integrated, tightly exploited, social System; he lives much more comfortably than Faraday, but at the same time until the necessity of producing regular output of patent able or advertising value, while avoiding all dangerous social or philosophical ideas. As a result, the worthies I mention were quite worried about the lack of scientific freedom in a planned society, but only indirectly and perhaps subconsciously as to what was actually happening to their own freedom in an age and time of extensive witch-hunting, where being called a communist was far more dangerous than being caught red-handed in a fraud or robbery.

These considerations, however, are mentioned only because they lead one astray from the main facts. There is an intimate connection between science and freedom, the individual freedom of the scientist being only a small corollary. *Freedom is the recognition of necessity; science is the cognition of necessity.* The first is the classical Marxist definition of freedom, to which I have added my own definition of science. Let us look closer into the implications.

As an illustration, consider the simple idea of flying. I am told that our ancestors in India had mastered some mysterious secrets of yoga whereby they could fly hundreds of miles in an instant. I don't believe it; these are flights of the fancy rather than of the body. Attempts to imitate the birds had very limited success, but gliders were more successful. Then came the posing of the elements of the problem, namely sources of power, methods of propulsion, laws of aerodynamics-all scientific and experimental truths. Mankind was not free to fly till the dying machine was invented. Today, anyone can fly without *yoga* - provided he has the means to enter an airplane. This, as society and its property relations are constituted, implies that either he owns the plans, or someone who does allows him admission; ultimately, the question is whether or not our flying human has money, i.e. the necessary control over means of production. In the abstract nothing prevents him from sprouting a pair of wings

and flying off like a bird; or from becoming a yogi and soaring into the atmosphere by mere exercises of will power. Such freedoms nevertheless, are illusory; necessity compels man to find other, more Feasible technical methods.

Take a commoner case, of eyesight. Five hundred years ago, extreme short sight or extreme far sight would have been regarded as varieties of blindness; they were written off as afflictions from heaven, or concomitants of old age. Glasses have to be invented for the restoration to normal sight of such people. This means today the science of optics, some knowledge of eye structure, of glass, including its chemistry, lens-grinding technique, factories, and workshops. There are still many people who suffer from eye-defects that could easily be corrected by glasses; they are legally free to wear glasses. Only lack of funds prevents them. In India the number of pairs of glasses really necessary but not available would, run into the millions.

We observe, then, that to recognize the necessity implies scientific experiment; in addition, there is a technical level, which cannot be divorced from the experimental. Finally, there is a social structure that is not only intimately connected with the technical level, but also conditions the freedom of the individual by introducing a social necessity that in the abstract seems unnecessary but exists nevertheless.

Some of my experiments about science are not likely to be disputed; that Science knows only one test, that of validity, of material proof. Science is nothing if it does not work in practice. Science is direct investigation of properties of matter, hence materialistic. Scientific results are independent of the individual who carries out the experiment, in the sense that the same action gives identical results. Finally, as the search for causes and their effects, science is cumulative: science is the History of science. Every scientific discovery of any importance is absorbed into the body of human scientific knowledge, to be used thereafter. Schoolboys can repeat Galileo's experiments, and first year college students learn more mathematics than Newton knew; the young students must go through much the same mental process, stripped of inessentials and repeated according to modern points of view, when they study. But they do not have to read Galileo's dialogues, nor the Principia. Here science differs essentially from the arts, for in painting, the modern painter need not study the prehistoric bison's in the cave of Altamira, nor the poet read Kalidasa. On the other hand, we can appreciate works of art and literature of all ages, for they are not subsumed in their successors in the manner of scientific discovery. Aesthetically, they have a survival value, a lack of obsolescence that the scientific work lacks. However, not all aesthetic effects have this survival value; the rapidly changing fashions that most ruling classes think necessary in their garments become as quickly ridiculous.

The other statements may also be briefly illustrated. Two painters painting the same scene will produce substantially different pictures; two people clicking the shutter of the same camera pointed at the same object will not. The fruits of ritual depend upon the rank of the celebrant, and only the king, medicine-man, shaman, or brahmin have the power or the right to draw down certain benefits for mankind; science tells us that these supposed benefits are imaginary, and fertility of the soil is better obtained by special agro techniques, chemical fertilizers, and so on, than by fertility rites. Moreover, the chemicals and techniques work in the same way independently of who applies them.

Now I give these examples deliberately, because both art and ritual performed at one time the functions that have been displaced by scientific observation. Primitive ritual was a substitute for what we now call scientific theory though primitive technique was correct. In India the menstrual taboo is still observed, though dying out in the cities, where the hurly-burly of industrial life deprived it of all meaning. Our workmen worship their tools on one day in the year, a custom not without charm can be traced back to the oldest known times; but lathes, turbines, electric motors and railway trains have made it clear that there is none of the workman's personal *mana* that resides in the tool. I note in the market that the humble vegetable vendor

makes the first sale of the day with a humble salutation to the balances, and to the goddess Bhavani; the share market speculator may spend considerable sums on astrologers, but doesn't neglect the market quotations, and relies upon study of trends and corners in shares, stocks, bonds, and, such modern financial jugglery which is absent in his and the astrologer's scriptures. The millions that bathe even now at the time of a solar eclipse can point with pride to the fact that their prayers have been successful, that the sun has always been freed from the claw of the demon who swallows him; but astronomical theory which predicts the eclipse to the minute has crept into our traditional *pancanga* almanacs, through the Western ephemerides, so that people cannot really believe in what has come to be an obsolete practice. *In science, practice and theory cannot be divorced.* This does not mean that scientists have never held a wrong theory, but only that they keep on making better and better approximations to the truth, knowing that there is no final truth simply because the properties of matter are infinite and inexhaustible. In ritual, no one dares make an experiment; the older the precept the more sure its grip.

Religion develops from ritual when primitive society acquires a class structure, a tighter organisation of its originally varied components into a larger whole. This need not be elaborated here. What most of us do not realize is that science is also a social development; that the scientific method is not eternal and *that science came into being only when the new class structure of society made it necessar*y. Of course, science really comes into its own with the machine age, which cannot develop without science and which in turn contributes highly useful technical aid to scientific discovery. But the fundamental inner connection is that machine production, like science, is cumulative. The machine accumulates human labour time towards the fulfillment of a specific human purpose. Yet modern science, as we know it, came into being before the machine age, and for the same purpose, namely to serve the new social needs. *Modern science is the creation of the bourgeoisie.*

One of the major contributions of science is that it separates theory from technique, specifically from productive technique. If you look at our village workmen, you find them still producing excellent work with quite inferior tools simply because the workman masters the individual tool, makes it an extension of his person. Only he can handle the particular bit of metal efficiently enough to obtain good results. But his production is not standardized. If he makes two complicated devices of the same type, the parts will not be interchangeable, though both may have the same design and function. In the modern factory, on the other hand, the lathe or the loom is independent of the person handling it, just as the scientific experiment is independent of the experimenter, provided in each case the worker has the minimum efficiency necessary to keep the mechanism from damage. A village weaver is whole ages and social layers apart from the village potter; a worker on the assembly line can easily shift from one type of factory to another. In the case of the handicrafts-man, theory is not divorced from the tool; his knowledge is acquired as well as expressed through his fingers. The result is that the transmission of such knowledge is slow, craft workers tend to form into closed guilds (in India Small sub-castes) and a long apprenticeship is necessary for the production of more workmen, their numbers and production being severely limited. This was the situation in Renaissance Europe, for example, when considerable accumulation of money with the merchant princes (and its overflow) made it necessary to find new methods of making money grow. The older usury was limited in scope: more than a certain profit: could not be extracted from the debtors tied to this older mode of production. Confiscating the mortgaged tools of a craftsman may lead to starvation for him and his family but the tools are unproductive bits of metal and wood to the usurers. There is needed a new class which can produce goods efficiently without long training, and whose surplus labour can be appropriated by an employer. This turns the mere usurer into a capitalist, the craftsman into a proletarian. But to manage such enterprises, there is needed some theory of material processes that works in practice, and, serves the managing class which does not handle the tools of production. This is

precisely the role of science. If you look into Galileo's researches, for example, you will find them concerned with such practical things as why pumps don't suck up water above a certain height - which leads to hydrostatics, and also to better pumps. Accurate time keeping is made possible by his observations upon the pendulum; but it is factory production, where many men have to be brought together simultaneously for coordinated labour, that needs accurate time-keeping; not cottage industries. Galileo cast or recast horoscopes, rather badly. His astronomy was revolutionary because he turned a telescope upon the heavens, to interpret what he saw in a perfectly natural manner. The man in the moon disappeared, to be replaced by mountains. But what made his astronomy dangerous was the fact that it shook a system of the universe taken for granted by the ruling class and by the church that served it; by implication, the rest of the social system was also laid open to challenge, something that no man is free to do without risk.

Science is not mere accumulation of experimental data. No experiment is great unless it settles some disputed theory; no theory is a striking advance unless it explains puzzling experimental data, or forecasts the results of unperformed experiments. But one has only to look at the way the scientific center of Europe has shifted to see the intimate connection between science and production, between the coming to power of a new bourgeoisie and the local age of discovery. Leeuwenhoek was a janitor in Delft who ground his own lenses and made the first good microscopes, which he turned upon drops of water and the smallest insects. It was the Royal society of London that sent its secretary to visit him, and published his papers, just as they published Redi's communications against the doctrine of spontaneous generation, which helped solve the very practical problem of food storage. But the idea of giving credit to him who publishes first is comparatively new. Even Newton did, not like to give away his discoveries light-heartedly, and the further back we go the stronger we find the tendency to keep a precious secret concealed as a monopoly. It is the social mode of production that changes the fashion, though private ownership of the means still insists upon patents, cartels, monopolies at level of technique and manufacture. Now is it an accident that the very century during which two revolutions placed the bourgeoisie in power in England produced Newton? How is it that the French revolution, which cleared off the rubbish of feudalism in France saw the greatest of French and European scientists: Lagrange, Laplace, Ampere, Berthelot? They rose with the bourgeoisie and survived Napoleon. Gauss, the great name in German science, appears on the scene at about the time the German bourgeoisie becomes the real power in its own country; and he is not alone. If we wrote all these off as accidents, we should be in the ridiculous position of denying the possibility of a scientific basis for the origins of science, by asking the history of science as a series of fortunate coincidences, though science is its own history and has always progressed by seeing the reason behind suspicious coincidences. I might go further and say that Greek science was (in spite of all the admiration lavished upon it, and in spite of its logical method, having served as inspiration to the Renaissance) not science in the modern sense at all, but pseudo-science, much as Greek and Roman capital can at best be called pseudo-capital in spite of modern imperialist tendencies and actions. The aim of Greek science was to reduce all phenomena to reasoning from the techniques that had originated the very discoveries. That too was a social necessity, for in classical society the work was done by slaves, whose existence was taken as a law of nature, a necessity which reflected itself in the scientific outlook of the time.

This should dispose of idea that science is the creation of gifted individuals, thinking for 'purely' scientific purposes among problems, which came to them out of some realm of the mind. There are gifted individuals in every age and society, but the manner in which they exercise their gifts depends upon the environment, just as much as the language in which they choose to do their thinking. It is as impossible for the mind to exist without thought as for the body to exist without motion. There are

still people in India who speculate upon the relative merits of Sankara's and Ramanuja's philosophy, though they do not thereby presume to acquire the prominence of those two founders. If I repeat Newton's experiment with the prism, I shall get the same results, but certainly not the same credit as a scientist or founder of optics. *The weight, the significance of a scientific discovery depends solely upon its importance to society*. This is why the college student, knowing more mathematics than all of Newton's contemporaries, is still not a prodigy. A discovery that has been assimilated is reduced to the level of useful technique. A discovery made before it is socially necessary gains no weight and social necessity is often dependent for its recognition upon the class in power. Leonardo da Vinci, whose 500th anniversary is now being celebrated, is the most famous example of this. He still served feudal masters, who were not interested, for example, in the manufacture of pins (from which Leonardo expected to make a fortune), and who used his mechanical talents for stage effects. A hundred years later, his fame as an artist would have been far less than an inventor. That social development, both in technique and in needs of production, evoked scientific discovery long before the days of organized research is clear from the independent and simultaneous discoveries made so often in the history of science. For example, the liquefaction of gases, so long considered impossibility was done by two different people in France at once. The Raman effect, whose theory is still imperfect, was discovered simultaneously in the USSR and India. The credit rightly belongs to Raman, who realized at once that while the rest of the world had been looking for an atomic effect, this was a molecular phenomenon. The experiments he devised proved it, and gave us a valuable technique of analysis, which does not change the substance.

But occasionally, as with Priestley, the conflict between the scientist and the class that dominates society becomes tot, great for the individual and for his discoveries to gain proper recognition. This is not a characteristic merely of the bourgeois period. During the middle ages, we find Europeans turning to meditation, the monastic life, theological speculation. Such tendencies were highly respected and advertised, with the assistance of an occasional miracle. However, the theology was not independent of the class structure of contemporary society: dangerous speculations led a man to the stake. Not only feudal rulers, but also the later merchant classes used theology, Protestantism in the latter case. The early saints and martyrs upon whose reputation the church was apparently founded, did not suffice in the later period. When the Church itself became a great holder of feudal property, abbacies and bishoprics turned into the prerogatives of particular rich families, or groups of families; this happened, incidentally even with Buddhism as may be seen from the history of the Barmecides, or of the few ruling families of Tibet till its recent liberation, or from the history of the richer monasteries in Ceylon. The foundations of Sankara, Ramanuja, and even a real people's saint like Tukarama are now chiefly preoccupied with methods of increasing their wealth, retaining outworn prerogatives, avoiding taxes. The wealthy Church in Europe needed the Inquisition to support its claims; that holy office found Galileo's thought dangerous. The crusades were diverted to strange aims, such as the conquest of Constantinople, and the suppression of a popular movement in the Albigeois. The Index Expurgatorious shows the church's attitude towards certain type of advanced thinking, while the last Spanish civil conflict demonstrated what steps the church in Spain, as Spain's greatest owner of property, was capable of taking against a democratic government.

A fairly close parallel could be drawn on the thesis that *science is the theology of the bourgeoisie;* at least it replaces theology whenever the bourgeoisie-capitalist mode of production displaces the feudal. The scientist must remain comparatively poor like the monk, but is admired, admitted to the board of the capitalist baron just as the cleric was to that of the feudal lord. His discoveries must be patentable, but he rarely makes the millions; Pasteur and Faraday received a beggarly Pittance of the profit made from their discoveries. A press agent may make the scientist's miracles known, but only if they are acceptable to the

lord of the press, hence to the ruling class. And most striking of all, in the period of decay, witch-hunting is as prominent in its own way as with the end of feudalism.

Though a creation of the bourgeoisie, science is not its monopoly, and need not decay with the bourgeoisie. The art of dancing began as part of ritual, but is now one of society's aesthetic pleasures even though the witch doctors who initiated it have mostly vanished. Music is no longer necessary to promote the growth of plants; even as I write, I can hear the primitive rhythm of tom-toms and ancient chants being practiced at midnight-not for better crops but for the sake of some relief from the daily grind of life by people who are milkmen, factory workers, and house-servants. Sculpture does not mean the underground mysteries of pre-historic French grottos; the Parthenon statuary is admired in the British Museum, but no longer worshipped. There is no reason for science to remain bound ally longer to the decaying class that brought it into existence four centuries ago. The scientist needs this freedom most of all, namely freedom from servitude to a particular class. Only in science planned for the benefit of all mankind, not for bacteriological, atomic, psychological or other mass warfare can the scientist be really free. He belongs to the forefront of that great tradition by which mankind raised itself above the beasts, first gathering and storing, then growing its own food; finding sources of energy outside its muscular efforts in the taming of fire, harnessing animals, wind, water, electricity, and the atomic nucleus. But if he serves the class that grows food scientifically and then dumps it in the ocean while millions starve all over the world, if he believes that the world is over-populated and the atom-bomb a blessing that will perpetuate his own comfort, he is moving in a retrograde orbit, on a level no beast could achieve, a level below that of a tribal witch-doctor.

After all, how does science analyse necessity? The sciences are usually divided into the exact and the descriptive, according to their being based upon a mathematical theory or not. This distinction has faded away because the biological sciences have begun to feel the need for exact numerical prediction, while physics and chemistry have discovered that, on the level of the individual particle, exact prediction is not possible as with the movement of the solar system. Both have found the new mathematical technique, based upon the theory of probability that they need. In the final analysis, science acts by changing its scene of activity it may be objected that astronomy does not change the planets or the stars; is it not purely a science of observation? Astronomy first became a science by observing the changes in the position of heavenly bodies. Further progress was possible only when the light that reaches the astronomer was changed by being gathered into telescopes, broken up by passage through spectrographs, or twisted by polarimeters. Parallel observations o~ changes, say in metallic vapours, in the laboratory enabled conclusions to be drawn about the internal constitution of the stars. There is no science without change.

If this be admitted, we are near the end of the inquiry. The reason why the scientist in a capitalist society to-day feels hemmed in and confined is that the class be serves fears the consequences of change such as has already taken place over a great part of the world's surface. The question of the desirability of such change cannot be discussed dispassionately, cannot be approached in a scientific manner, by the supposedly 'free' scientist. The only test would be to see the two systems in peaceful competition, to see which one collapses of its own weight, succumbs to its own internal contradictions. But the scientist who says that this should be done finds himself without a job if he is on the wrong side of the "iron curtain." The real task is to change society, to turn the light of scientific inquiry upon the foundations of social structure. Are classes necessary, and in particular, what is the necessity for the bourgeoisie now? But it is precisely from cognition of this great problem of the day that the scientist is barred if a small class should happen to rule his country. Perhaps the crisis cannot be considered immediate in new democracies like India, where the bourgeoisie is itself a new class? This is incorrect. The new class did not develop its own

science any more than it invented its own Indian steam engine and motorcar. Just as they import the best paying machinery, the science they need is also imported in ready-made form. They are also ready to import any political ideology that serves their end. This means that instead of the centuries of development from medieval to modern as in Europe we can expect at best decades in India, under the leadership of a bourgeois-capitalist class that has only re-oriented but not lost its colonial mentality.

3. THE SOCIAL FUNCTIONS OF SCIENCE:

Review of J.D.Bernal's Book

In place of the usual blurb, the cover jacket contains two brief line; that almost eliminate the task of the reviewer " What Science Does! What Science Could Do?" But besides containing this surprisingly accurate description of its own contents, the book is unique for the performance. A Scientist of repute has approached the problem of the relationship of Science to Society in the same way as be would have approached any other scientific problem requiring original thought and research. He has dealt in a painstaking manner with every aspect of the subject, subordinating each detail to its proper position and emphasis in the general scheme. The result is a valuable book for everyone who wished to study science today, even in detail. The contributions such as the appendix on films duplication will be profitable to any working scientist.

A detailed examination of the book is beyond the scope of any short review. But the author's thoroughness can only be described as admirable. He not only gives balanced and well; considered schemes for the organization of research, but even goes at the problem from the proper take-off by considering the several attitudes shown towards science by leaders of (British) scientific thought. There is analysis of the: way science is coordinated (or left without co-ordination) in every country of the world; there is also a serious and apparently successful attempt to judge the energy spent on scientific work in each country. Finally, we are shown what planning could do in science itself, as well as for the whole of Society. There is none of the Utopianism of Wells, nor his foundationless optimism (in the 'Autocracy of Mr.Parham', or 'the shape of things to come'); nor the reaction shown, to this by people like Huxley (Brave New World) but both are analysed as well as avoided. The pessimism of Russell ('Icarus' or the systematically erroneous 'Prospects of Industrial Civilization') is treated with silent contempt. The dangers of the idealistic approach popularized by Messrs Jeans and Eddington are noted, yet Bernal has escaped the all too common error of adopting the pontifical attitude of these people for his own arguments.

What Bernal says about science in India cannot be left unquoted, if only to show that there can exist a person with a thorough grasp of the problem in the same country that published a magazine like Nature, containing articles on the importance of keeping up the proportion of "white" men in the educational and administrative services of a colonial country In order to preserve a high standard. We have here refreshing contrast. I hope that my own commentary in square brackets will not be felt an intrusion.

"...... The maths of Ramanujan and the physics of Bose [physiology would be better, as Bose left physics rather early] and Raman have already shown that Indian Scientists can reach the first ranks. Nevertheless the difficulties under which Indian Science suffers will preclude, as long as they last, any large-scale development, or more particularly, any serious influence of science on Indian culture. It is inevitable that in science, as in other aspects of life, the Indian should feel the need for national self-assertation, but his attitude is always an uneasy one. The Indian scientist must, in the first place, learn his science through English channels and be subjected to the patronizing and insulting habits of the English to their subject races. The reaction to this breeds a mixture of submissiveness and. arrogance that between them inevitably affect the quality of the scientific work. Indian science is noted at the same time for the originality of many of its conceptions and experimental processes, and for the extreme unreliability and lack of orifical faculty in carrying out the work itself." In particular, the last sentence is almost exactly what the Arabic scholar and traveler Alberuni said about Indian science nearly a 1080 years ago, characterizing it of as a mixture of cow dung and pearls. I can say that this is about the sanest criticism of scientific work in this country that I have been given by any foreigner. To continue:" Needless to say, Indian science, like everything in India except the English Civil Service and the Army is starved of funds. He may have mentioned the Indian National (,)" with these]. The total allotment or expenditure for scientific research in India is not more than Pounds 250,000 [a good portion of this goes in fantastic salaries to quite useless persons] which would be equivalent to 1.50 of a penny per head of population, or 0.015 per cent of the miserable national income of Pounds 1,700,000,000. Yet there is hardly any country in the world that needs the application of science more than India. *In order to release the enormous potentialities for scientific development in the Indian people, it would be necessary to transform them into a free and self-reliant community. Probably the best, workers for Indian science today are not the scientists but the political agitators who are struggling towards this end"* (Italics mine).

After this fair appraisal it would be our duty to say a few of the things that the author has left out for lack of space, or of malice. The research work today in this country is confined to the universities and to a few special institutions, controlled by and often actually worked by people who know nothing of science. Though it is no longer the custom to shove all the fat jobs of the educational system to one side for third rate Englishmen who cannot be accommodated in their own country, the mark of the beast has by no means been eradicated. The men who occupy the key posts have obtained them by other means than research ability, usually by pure charlatanism, bootlicking, and politics of the most decadent sort within academic circles. Effective control of education, as of everything else, was in the hands of the bureaucracy; educational institutions were always run on government sufferance, and usually on government grants picked out with the meagre income obtained from student's fees. Under these circumstances, it is not surprising that the Indian "Professor" was a parasite on the already parasitic official services, assiduous only in licking the boots that seemed capable of kicking him the hardest, reactionary in politics, and proud at best of having helped some of his students to the supreme bliss of admission into the Indian Civil Service. Research was a difficult proposition for such people. (...)" Scientific activity that has come out of England in recent times, the book is certainly worth possessing. No matter what the advances in scientific technique or the structure of society, this work will remain a clear presentation of the achievements and aspirations of science, as even of a good scientist in 1939.

4. PROBLEMS OF SCIENCE AND TECHNOLOCY IN UNDER-DEVELOPED COUNTRIES.

What I have to say here is, admittedly, going to be unsatisfactory for two reasons. First, most of us know what our problems are; secondly, I have no spectacular solutions to offer, only a rather small technical suggestion or two, which may help analyse the particular problems in each case, and may help towards a planned solution.

The Context

The background is all - important. Most of us are so deeply concerned with science and technology that we forget the context in which both science and technology must be applied. The context may be divided into three Darts, deeply inter-connected: Political, Economic and Sociological. After all, we have no special science or technology of our own, Arabic science or Indian algebra; once the leading disciplines in the world, are both out of date. One cannot speak of African chemistry or South-East Asian engineering. Science and technology know no national frontiers. Therefore, the background before which they must function becomes a prime consideration for us.

The political situation is all-important. Most under-developed countries have been under foreign domination for a long time. That is, in fact, the primary reason for their being underdeveloped. So, freedom must come first. We cannot speak of science and technology for Angola and Mozambique, for example. The South African situation is even more complex. The land has a few outstanding technological developments; their laboratories and engineering works are by no means to be despised. But the real Africans are not even citizens in South Africa, which remains for them under-developed, while being in a quite satisfactory stage of development for property-owing whites and for the investors in London who stand back of them. A similar situation is true, with lesser development, of Rhodesia.

In such cases, we have no solution to offer, for our conference restricts itself to science and technology. However, the context tells us that the special problems in such countries cannot even be discussed here. There may be some exceptional possibilities. Perhaps, Hong Kong may claim to be one of those exceptions. But it would be difficult even here to consider the problems of Hong Kong without a solution of the obvious political question.

The second point, which too many tend to regard as the main problem, is economic. In fact the very word under-developed has this connotation, namely economic underdevelopment. Most of our countries lack the necessary resources for development along with the actual manifestations of development: electric power supply, factories, railways and shipping, roads, motor transport, airplanes, and of course, consumer goods and decent housing. The lack of resources is fortunately not present in all countries. Several Arab lands have discovered in oil and natural gas a commodity, which can be exploited sufficiently well to solve their economic problems. However, whether the oil and other resources are properly used or not depends once again on the context. First, the foreigner must not take away the lion’s share, as happened in Iran for so many years. Secondly, those in power must feel the need for developing the country rather than for building palaces for their own families and living a life of Arabian Nights Style. This remains, therefore, again an internal political matter, namely who plans and for whose advantage. It is not sufficient to announce grandiose plans; one has to convince the people that they stand to gain and to secure popular support. Development in Ghana and Indonesia show what happens otherwise. Going deeper into this question but that would cause unpleasantness.

However, we reach one important principle here: *under-developed countries need a planned course of development, which necessarily implies a planned economy.*

Merely admitting this principle is not enough. The context once again thrusts itself upon your attention: who does the planning, and for whose real advantage? The solution generally offered is to invite foreign experts to offer advice and draw up schemes. With the best will in the world, this will not succeed. The foreign expert has been used to planning for an entirely different purpose, in totally different surroundings. He pays little attention to local needs during the course of development. Oftener than not, the foreign expert is interested in selling the products of some companies with which he might be connected. Here, we could learn a good deal from Chinese experience, were it not for the political problem, once again, which makes it impossible to secure co-operation from that great country at such a meeting. But let me give some simple examples to illustrate what I mean.

In our sugar-producing co-operatives, the bagasse was burned for fuel. One brilliant and remarkably honest foreign expert suggested that this wasted most of the contents of the bagasse, except what remained in the ash. The cellulose could be used in paper manufacture, the wax and oils extracted for other purposes, and so on. In fact, Indian chemists had actually analysed the possibilities so that no foreign expert was needed. It was suggested that the paper factories be set up, by the co-operatives or sugar companies themselves, and the bagasse used to proper advantage. But in the event this could not be done economically for two reasons. First, the Factory machinery would all have to be imported. Secondly, the amount of bagasse withdrawn from the fuel used in sugar manufacture would mean greater outlay for other fuel. Oil is too costly; we have no natural gas in the sugar-producing regions, and coal meant additional strain on the transport. In any case, the extra fuel costs would have made just the difference between a successful cooperative and one running at a small deficit half the time. The solution in the present context was given by Hungarian experts. They suggested, and worked out in data a scheme for using the bagasse as fuel without losing all its value in other ways. The stuff was to be fermented in vats, and the gas used as fuel, converting one or more furnaces completely to gas burners, as the total amount of bagasse would, not suffice to stoke all furnaces. Then the wet sludge could be put directly on the fields, with every substantial savings in fertiliser. In fact, there was an added advantage in lightening the soil, which would be ruined by steady application of chemical fertilisers over a number of years. Finally, I pointed out that there would be an educational advantage: The peasant members of the cooperative could use the method for their own surplus bagasse, and also for cattle dung. At present the cattle dung is dried into cakes and used for fuel, again destroying its value as fertiliser. Gas generated from such waste products would save ail the fuel value without affecting the fertiliser value, and make for easier cooking as well.

The scheme has not been adopted, after all. The reasons were political and sociological, for the people who were to make the final decision had other ideas of their own, when they had any ideas at all. We still go on wasting the bagasse, though a factory or two for paper will eventually be set-up with foreign expert advice, of course.

The Sociological Context

Hitherto, I have only pointed out the difficulties without suggesting a solution. As a matter of fact, I hold very strong views on the proper political structure and the correct foreign policy for under-developed countries; but this is not the time not the place to a develop those views. We are not here to offer political advice nor to suggest political courses. Similarly for the economic situation. Most countries want and ask for capital. This conference cannot provide it, nor can it suggest means of raising funds. The scientific approach, on the other hand, tends to be rather vacuous and devoid of application unless these primary difficulties are solved. At least, we have proposed one main must be planned, and the principle, namely that the economy course of full development charted in outline, rather than left to individual initiative which means leaving it to private greed. Most of us fail to ask why our countries are underdeveloped, when we go begging abroad for financial aid and technical experts. The reason for underdevelopment is precisely that our raw materials and our great markets were exploited by the foreigner to his own advantage. Our products were taken away for the price of the cheap labour needed to take them out of the earth, and we paid the highest prices for the finished goods. In a word, the developed countries with very few exceptions are developed precisely because they made profit both ways from us; we were never paid the actual value of the things taken away. It is our resources that have helped in the development of the great industrialized nations of the world; yet we have to go to the same nations as suppliants, not as people demanding return of what is rightfully our own. Naturally no such demand could be enforced, even if it were made.

The foreign domination, whether in the form of colonialism or by other spheres of influence, has left an unfortunate mark on the society of our countries. The very languages we speak at such meetings are those left to us by the foreigner. This would not be bad, were it not for the insidious foreign way of thinking that too often goes with the languages. Most of us become honorary Englishmen, or Frenchmen, or the like. The models seen in New York, London or Paris don't seem out of reach in Bombay, Calcutta or New Delhi. But go a few miles away into the unaffected countryside and you will feel that you are in a different land altogether. Our development is not uniform. Attempts at catching up with foreign lands should not, but always do, accentuate the differences that already exist between towns and country.

Illiteracy, lack of technical education, lack of transport, paucity of telephones, cinemas, radio sets, absence of television all these seem impossible hindrances to any foreign or foreign trained expert. Very few people see the need for and the possibility of development by getting the common people interested and by using the techniques available in the countryside. Let me again give an example of what I mean.

During the Japanese occupation, when all major industrial areas of China had been taken over and the Kuomintang armies pushed into the backlands, the problem of supplies became desperate. Chiang Kaishek needed two million blankets for his armies, with no way of importing them from abroad. The blankets were supplied by a remarkable man and a remarkable movement, the Gung Ho (Work Together) cooperatives formed under the direction of the New Zealander REWI ALLEY. He knew China well having worked with its common people for over twenty years. The blankets were made by handicraft methods, were of satisfactory quality and capable of standing up under rough wear. Moreover, they were supplied in less than a year· The methods by which the work was organised, with the overwhelming majority of workers illiterate, scattered in small units over nearly two thousand miles, were undoubtedly the most astounding feature of the entire project. I only wish the history of Gung Ho were written published and made available to all underdeveloped countries. In this case, Alley worked out a system of accounting that did away with almost all-clerical work. 'The workers organised themselves in such groups as they liked, whether by families or by local crafts-guilds, with Alley guiding them in each case at the beginning. The wool was produced by the shepherds of the back-lands. Per bale of wool supplied to the spinners, one colored bead was put in a bag. When a bale was used up on the spinning wheels one bead was taken out of the bag, so that the residue could be tallied with the stock in hand. Per unit of yarn produced (large hanks), a bead of a different color was put into another bag. Similarly for the yarn supplied to weavers and units (blankets) woven. This system worked without a hitch and without a penny lost, with almost no paper work. It furnished employment to the neglected areas, and blankets for the soldiers.

I wish the story could end here. Unfortunately, the blankets, delivered to Chiang's officials did not all reach the soldiers. Not a few went into the black market. Other corrupt officials managed to get themselves jobs as managers of district co-operatives or of the large factory units, and stole as much as they could. At the very top came Chiang Kaishek, the CC group, the Kungs, Sungs and their selected henchmen, stacking away gold in the USA and letting the war take care of itself. The Academy of Sciences (Academia Sinica) had been evacuated to Chungking and Kunming. I recall making and sending copies of scientific papers from India for: them to help research that had no connection with the war or national needs; in some cases, Z had also to arrange for publication. A few noble scientists and scholars were studying in India on generous subventions. One captain in the army had taken long leave to study Indian philosophy, while his company was fighting in the frontline; he managed to get through the war years without difficulty. In other words, the social and political context was, after all, the determining factor.

Nevertheless, let me draw one more basic principle from this: In technological matters, particularly in consumer goods manufacture, use local technique, organised by drawing in as many of local producers as possible. Naturally, this means primary producers, not the moneylenders, nor landlords. It also means organisation without bureaucracy.

I have to make clear to this point the fundamental difference between this method and philosophy of hand spinning on the hand wheel, charkha. The charkha is inefficient and uneconomic as a full time implement of manufacture. The late Mahatma Gandhi discovered mystical qualities in the art of hand spinning which raised it above yarn manufacture on power spinning machinery. Having gone rather thoroughly into the statistics of the resultant khaddar cloth, I can assure you that its effect was political, but nothing to speak of in national production as such. It shamed people into boycotting British imports before the war, and provided a badge for the revolutionary. Today, khaddar cloth is a drain on the Government budget and a mark of the professional politician or his servant. This is in strong contrast, however, with handloom products which provide excellent patterns and has been a valuable aid to India's export drive. The handloom, which means mill spun yarn, can be used as a part-time tool of production, especially in seasons when agricultural operations are slack. It saves transport of cloth and can break the shopkeeper's black-market monopoly if used with proper care. It is also of considerable help in drawing partially disabled and otherwise unemployed people into useful production. Finally, it is simple in operation and easy to manufacture with local tools and materials. That perhaps, is the essential difference between what I should call the Gung Ho approach and the Gandhian: Use whatever local methods you can to produce consumer goods, while heavy industry is being built up.

Planning

If science and technology have any use at all, they must fit into a plan. This does, not infringe the freedom of science, nor of the scientist in underdeveloped countries. There is an essential difference between the scientist in backward lands and his teacher in those parts of the world where science had long been developed. The latter is amply supplied with the costliest apparatus, good libraries and reference material, and a large number of auxiliary technicians. Such a scientist in advanced countries has often to fight for his freedom. His funds may come from some government project, dictated by third-rate bureaucrats who insist upon secrecy for discoveries that ought immediately to b~ made public. Often, top scientific talent is wasted in defense projects. This cannot be the case with underdeveloped countries. Mostly, they have no scientist of the first rank in world science, not even of a high second class. To speak of freedom of such scientists to do what they like at someone else's expense is to allow them to waste public funds in duplicating bad work done by second-rate technologists in Europe or the U.S.A.

Let the scientist be free, but let him earn his living by doing something for his country that comes in the category of vital needs. For example, many of you here are bound to be impressed by India's advance in science and may even persuade your own governments to copy us. But in what particulars? We have top class physicists, for example, our department of atomic energy is spending several hundred millions a year on an imposing establishment. But how much atomic energy is this country actually producing? The plant that should have been in commission in 1964 will not be operating till 1968 at the earliest. The delay has passed without criticism, while some politicians demand that we should produce the A-bomb to put us on at par with the big powers. In effect, the establishment we have was built by foreign 'experts', is outdated already, and will produce atomic power if run as designed which is costlier than such power elsewhere and costlier than conventional power in India. Even then, all the basic cost will have been off under the heading of 'research', (Science, or some such beautiful title).

Again, don't misunderstand me, India, like every underdeveloped country on the road to industrialisation, needs every

sort of power it can get. Costly as it is, atomic power will be cheaper than human muscle power or the power drawn from bullocks. But is it the best source under our present economic conditions? Almost all the countries represent here have a much better and. cheaper source of power available for their development, Solar Energy. This has the defect of being irregular, but can be put to uses where regularity is not in demand. For example, pumps for irrigation, of 5 to 10 horsepower capacity, run by solar energy would help our agriculture immensely. This would not need centralized administration and a fantastically top heavy basic establishment. If mass-produced, the pumps would be cheap; their fuel costs nothing at all and the irrigation they provide would be a real godsend. Maintenance would be easy and would also help mechanise the population in the most backward countries. Similarly for cooking by solar energy. This will not only save such fuel as oil, but (in most of our lands) the firewood thus saved means reforestation on countryside now denuded. Without such reforestation, no real agricultural reform is possible, as we all know. The desert can be reclaimed, using the very sun that now blast it. I say all this only to point to a further principle: In planning, work out the complete economic cycle at each stage. With solar energy, the cycle naturally included reforestation and development of agriculture, just as in the use of bagasse the land crop cycle was to be restored. Science does not mean working with a few test tubes but for a whole country on a countrywide scale.

The last point can be driven home a little better. The cashew nut brings such high prices on the world market that many countries, including India, plan to increase cashew plantations to the utmost. I know something about this, having owned one of the best cashew producing farms in Goa, years ago. The tree grows with virtually no care, in the deepest jungle. But it kills the under bush completely. The water level is immediately reduced and erosion sets in. Where the cashew fruit-pulp is dumped not even grass will grow for years afterwards. The proper utilization of cashew plantations would require a strong chemical industry, which would utilise the powerful phenolic byproducts of the tree, fruit, and nutshell now entirely wasted. This again means a better: developed country than most of us have the good fortune to live in. Should we give way to immediate greed, as some of our State forest departments are going, it will ruin what is left of the forests, for relatively small gain. The cashew plantation must be properly terraced, so as to retain the water even when the cashew trees have killed off other vegetation. I could multiply these examples forever. The coconut trees that are so striking feature of our coastal strip have yet to be properly exploited. Most of what can be done is known to our coconut research institute, but hardly anyone knows that the institute exists. The husk (coir) can produce rayon, the trees improved by genetical selection the oil processed by more efficient methods and factories, the final product scattered through the plantations. But this implies an efficient and effective method of planning which we do not seem to possess. Our planning commission writes excellent philosophical discourses, completely futile when it comes to effective translation into useful practice. The private sector wants immediate profits, and the public sector prefers large-scale enterprises, which photograph well, get newspaper headlines and are useful in election propaganda.

Let me give an example of inefficient planning in which I was personally involved. The problem was one of dam construction. If the dam be too big, money is wasted; if too small, there is the risk of running dry too often. Suppose that we want dams, which on the available rainfall and run-of figures will not run dry oftener than once in twenty years, in the long run. What is the correct formula for estimation of capacity? The experts quarreled, so the problem was put up to me. It was a simple matter to give the right formula, based on R. A. Fisher’s test. But when I looked closer into the data, it was clear that many of the figures had been fake. Actually, the water run-off for certain years had not been recorded at all. The entries had been made by fitting a linear equation from the rest of the data against the rainfall figures, which were accurately known. Finally, looking into the map of the area it was possible to show that large dams would be of no use as compared to many very small dams which would help

terracing and would retain monsoon water more efficiently. Small dams are of no use for power supply, but much more useful in a monsoon country with eroded lands, for agricultural purposes. Moreover, the labour supply and most of the materials are local; very little cement and no machinery would be needed. This has not only the further advantage of economy but of easing distress among the villagers by allowing them to earn some money while improving their own lands. Very little cropland is flooded by such dams, though the total amount of water conserved is nearly the same as large dam. In the event, my formula was adopted because the expert could propose as his own, (he secured a promotion thereby). The remaining suggestions made by me never came before the meeting to which I was naturally not invited.

Statistics

Hitherto, all my suggestions have been critical and to a considerable extent negative. Let me speak of one special technique in order to make a positive contribution. This is statistics, and would be useful for any sort of planning, whether by indigenous or foreign experts, or simple allocation of resources. In fact, no planning can be successful which does not use good statistics correctly.

Statistics means the census type of complete enumeration, to most people who hear the term. However, counting everything is rarely possible and often not even practicable in most underdeveloped countries. The necessary staff is not available; clerical services remain slipshod or inefficient. Worst of all, people give wrong information because they feel that the figures they offer would in some way be of benefit to them, say in saving taxes or getting some government grants in aid. Finally the process of getting accurate statistics of this type is slow while inaccurate statistics is worse than useless. It is all very well to suggest that areas under various crops could be quickly measured and even the crops identified, by air photography. I know that this is true. But bow many countries can afford air photography and have the expert staff for evaluation? India has first-rate statisticians, but they are afraid that air photography may mean lack of jobs and retrenchment, so label it as 'unpractical'. Let me add that for all the fame our statisticians have secured abroad (and the large number of theoretical papers which form an impressive background for an even larger number of blue book reports) our statisticians have failed in their main job, through no fault of their own. They have not been able to say exactly how much food is available from last year's harvest. As a result, we have several different sets of estimate of how much food Indict needs to import, whether as loans, gifts, or by purchase. I have seen it in print that five, seven, ten, fifteen, even twenty percent of our grain is eaten by rodents and vermin. No one knows how the figures were obtained. If so basic is a problem as that of food cannot be handled by really able men, their is something wrong in the way in which the men are used. We are led back again to the social and political context.

Granted the will to use statistics properly, there are now better methods than the census, quick as well as inexpensive. These are labelled sample surveys; the technique is very well known. One counts a small percentage and estimates the total. Besides, there exist methods for showing the limits of accuracy of this estimate, so that a suitable margin may be allowed. I do not mean to go into details, which will bore most' of you. But if enough is known of the various types of villages, then a sample of not more than five per cent of the villages, and often one of less than one per cent would suffice to give all essential information. The sample has to be scattered properly, every type of village must be proportionately represented. Some common sense has to be used. The actual sample must be studied efficiently and information about it obtained with complete truth and accuracy.

This type of sample survey gives data within a couple of weeks, which would take over a year to obtain the complete enumeration. Its main uses are two: in industry and mass-production for control of quality and uniformity of the product. For

example, cement from different kilns in different places differs in quality. Even different runs of the same kiln show a substantial variation. But the engineer can allow for this in his construction work if, with each run, he is given a test figure of the average strength and the standard deviation. These can be calculated by one person, with a double handful of cement from each batch, properly sampled. One such statistical assistant could easily be employed by every cement factory, sugar combine, or similar industrial enterprise. The total output of such enterprises, of course, is easily counted; in such cases one has both the census type and the sampling type of statistics.

With the agricultural raw materials, the situation is entirely different. Without a good forecast of the crop in advance, it is not possible to plan for export, for processing of the raw materials, or for that matter even to avoid famine. This forecast can easily be provided inspite of great local variation by crop cutting experiments before the complete harvest is in. There are, naturally, even more efficient methods. Given the variety of seed, machine planting is practiced, simply counting the number of plants actually growing in uniform squares and taking a few ears from each square gives a surprisingly accurate estimate. I have seen this in the Dobruja, in Rumania, 400 plants were put down mechanically in each square meter; and the counting frames were one meter square. The reports were sent in by the wheat cooperatives in this case, and the central institute gives the crop estimate well in advance, allowing for natural disasters such as flood and drought. Not all of us are so fortunate as to have such large co-operatives and machine planting of wheat. In that case, I suggest that local experience could be used.

Local experience means that the peasants must have been on the same land, for some years, must know the particular variety of seed used, and must have farmed with the same technique. In that case, the Indian peasant can give an estimate within 6.5 per cent or better. The Chinese peasants, to my great surprise, could give estimates closer than 3.5 percent; the trouble in China (as of 1960) was an inefficient and bureaucratic central statistical organisation, which could give nothing accurately till the harvest was over and half-eaten. All their forecasts were revised again and again, set often as to be useless. They were gathered by the slowest possible methods, namely filling out Terms and everything, sending them to local headquarters, and eventually to Peking. Neither the statistical man nor the leading scientists had bothered to ask the peasants how they estimated the crop, nor even to compare estimates in routine yield. With our peasant, the trouble is to make him believe you that giving a truthful estimate will not lead to extra taxes. The difference between the illiterate peasant and the trained statistician is that the peasant cannot make large calculations; on the other hand, if the peasant is wrong in the estimate he makes for his own use (whether he tells it to government agents or not), he may starve. The statistician doesn't have to live by eating his estimate or his standard deviation. The difficulty in the field is always getting a truthful figure from the peasant. In China, this difficulty did not exist, but no one bothered about the peasants, estimate before I tried to evaluate it. Money lenders, landlords, middlemen purchasers and other interested parties including the profiteering grain dealer from the big city see to it that the truth is hidden when it is to their advantage to hide it. Once again, we come back to the context. There is a clear limit beyond: which you cannot go by ignoring the social and economic conditions prevalent in the country.

One type of sample statistics is a valuable adjunct to democracy, namely the opinion poll. In developed countries, this is oftenest used by business firms to estimate the success of their advertising campaign, the popularity of their products (soap, tooth-paste etc.) and such profit making ventures. The politicians' use it to see which way public opinion is veering. The number of people sampled even in so large a country as the USA need not exceed 700 to 1000, so that a small trained staff can give the result (From the start of the sampling to the final figure) within a week at most. But this is not practicable in most underdeveloped countries. Let me suggest the use of another technique, to be used with sampling, but on different principles.

This is called Mass Observation, and was first developed by the British anthropologist B. Malinowski. It was very useful in wartime England. The main idea is to let a few selected people express their own opinion on some points in their own way, instead of asking specially framed questions that could be answered either yes or no, or in some other specific manner. The result in Mass Observation is less easily calculated than by the sample-survey, but gives much more information to the trained anthropologist or to any intelligent administrator. It reveals unsuspected needs that cannot be brought out by the western opinion poll. But once again, truthful and frank expression by the person questioned is absolutely essential. He or she must be guaranteed and convinced, of complete secrecy; and must be free from fears of reprisals for speaking too frankly. Such observation has been used with great effect in Poland, by the Wroclaw Sociological group. Let me suggest that those of our; countries that struggle towards democracy would find it a useful way of ascertaining democratic goals and popular wishes.

5.THE SCIENTIFIC ATTITUDE AND RELIGION

In what follows, some social aspects of religion are considered in so far as they serve to keep India a backward country. The methods of cure suggested are by legislation, education and improved social conditions, with a brief example or two to bring out the basic idea in each case.

Reports by great religious leaders of the past show that they regarded their own experiences and revelations as the most exhilarating and profound happenings of a lifetime. But the details show that exactly similar and often-identical experiences may be had by the use of certain drugs, electrical stimulus of the brain, lesions of the cerebral cortex and in dreams. The trouble begins when people impose their views, on the basis of such experience, upon others.

My treatment of the phenomenon is purely materialistic, no matter what the source of the revelation. Argument with men or religion on their own ground implies that their sacred books or some other sacred books have a peculiar intrinsic validity, not to be challenged by experiment or reason. I am not prepared to admit that religion cannot be understood or discussed by a man of no faith, This comes to saying that only a confirmed drunkard can be competent to deal with alcoholism. Whenever reform from within succeeded in India, the result was the addition of one more sect to the innumerable existing sects.

The figure of speech about alcoholism has been deliberately introduced. Not only wine but also mescaline and other drugs have formed the core of ancient or primitive modern religion. The potent *soma* of the sacred *Vedas* was a drink of this sort too. Hashish was a reward for and stimulus to the murder of inconvenient opponents, as used by a fanatical Muslim sect of the Middle Ages in Asia Minor. The drug and its use gave rise to the word assassin. The sect itself changed into the more innocuous one of the Aga Khan. Religions have recognized kinship and rivalry between the spiritual and the spirituous. Thus Buddhism and Islam banned wine. If such a ban can now be defended on grounds of social necessity and prohibition be made part of a democratic constitution, why should other hallucinogens not be treated on the same basis? And what more powerful hallucinogen than religion?

There is one difference that drugs can generally be relied upon to produce exaltation. Its purveyors are taxed and subject to regulation, while the individual who uses them has to observe public decorum and, is severely punished for breaking law and order. Curative treatment is given to addicts. We have been very slow and hesitant in dealing with the purveyors of religion on

the same basis. Only the most gruesome malpractices have been banned: sati (widow burning; defended as 'voluntary' by many pundits), hook swinging, and the most obscene features of the *holi* festival are now forbidden. The last comes directly from prehistory; even Asoka had trouble with the institution,

But we have stopped halfway. Pilgrim taxes are levied by many places (Banaras) whether the visitor is a pilgrim or not. Why not tax all income from any religious source, including the 'voluntary' contributions from the pious? Why are temples and mosques not taxed on the same basis as many buildings reserved for the use of a special group? Marriage and divorce are now regulated to some extent by civil procedure; monogamy has become a legislative measure, regardless of religion. Why not secularize these social institutions completely and compulsorily?

Some people, although willing to admit that Indian religion has its harmful aspects, insist that education is the sole remedy. It is not, of course, but there is every advantage in educating people out of their superstition. That is one way of improving Indian education and social conditions, provided education is understood in a sense far wider than that of the schoolroom. The crudest of Indian superstitions is faith in astrology. Millions still bathe at a solar eclipse, not as a hygienic measure but to free the sun from a demon of darkness.

It is known, however, that there is no longer a risk of perpetual darkness if the ritual bath be omitted. The precise time and duration of the eclipse is predictable long in advance, not by the Brahmin's stock in trade but by Newtonian theories of the universe. It is not enough to make this fact public, namely that the Indian almanacs surreptitiously borrow their information about eclipses from foreign sources, while retaining the tripe about planetary influences upon horoscopes.

The *panchang* almanacs sell by the hundred thousands all over, the country, each area having one or more of its own. Their very existence must be turned to good use by inserting useful information: first aid hygiene, element of legal rights for the citizen, possibilities of getting aid from sources other than the blood-sucking money lenders in time of need and so on. Let the planets stay, and give their positions by all means; but make the traditional almanac into a really useful educational document.

Here the modern educator is definitely at fault. He works through a bureaucratic mechanism originally imposed by a foreign government and allowed to continue by inertia. His own education has, more often not, consisted in learning foreign books by rote where his grandfather might have recited Sanskrit texts with as little understanding. Often, he can teach the latest scientific theories in school and maintain outside the classroom that his ancestors three thousand years ago could fly through the air by the power of yoga and see the atomic nucleus and viruses by their inner sight. He never turns scientific methods upon the study of superstition. Why did the superstition arise? Did the Indian almanac ever perform any useful function at all? If not, how can one account for its rise and spread?

The basic fact is that the whole of Indian agriculture turns upon the monsoon. The annual rains begin at about the same time every year in any given part of the country, but the land has to be prepared for the sowing well before then. Similarly, the harvest has to be taken in after the last normal rain has fallen. But the calendar is a very advanced scientific concept in primitive life, determined mainly by long observation of the positions of the sun, moon and planets. We know that these heavenly bodies merely mark time: for primitive man, they made the weather as the very word meteorology indicates. So, they also seemed to control man's destiny. These all-powerful stars would have to be propitiated according to the priest's instructions.

To counteract this, education is the best method. Just as eclipses can be predicted, the onset and strength of the monsoon can also be predicted. Not as accurately as astronomical phenomena, but much better than the *varsha-phala* ('yield of the rains')

given in every Indian almanac. It is easier to send out storm warnings by radio and much quicker too. With radios in every key village, the farmer could be advised - *given an efficient weather bureau* - when to sow and to harvest. But this means leaving the *panchang* almanac alone. If we do this, superstition will survive much longer, and may be perverted to strange uses by some interested people.

The best way is to have a reasonably efficient long-range weather forecasting system. This is now well within our reach with air-mass analysis and observation satellites. The information must then be put into every almanac and the basis of calculation carefully explained in simple language. The peasant will see for himself that the stars have nothing to do with the weather or the monsoon and will be willing to listen when other bits of really useful scientific information are given. Even now he knows that fertility rites are much less effective than the proper use of fertiliser. But we must not throw away the magnificent chance of utilizing an old institution like the almanac to cut down the very superstition it promotes.

The last section says in effect that *tout comprendre* is by no means equivalent to *tout pardonner*. Let use try the method on the most obscurantist of all Indian religious and social institutions, caste. The evils of the caste system are known, but no one asks himself why the system originated and why it has held on in spite of so ·great a change in Indian life. Why should the Brahmin's pretensions be believed when he puts his sons to work in an office, which uses only English, not Sanskrit, and is perhaps headed by a beef-eating sahib?

The answer is quite obvious. Caste was socially useful at one time, when production was at a much lower level. It was the one way of keeping people together in co-operative effort rather than have every man strike out for himself with the common ruin of all. The village was the firm basis of caste, because land was generally held by a kinship group. Tenure of land and membership of the group went together. Whoever was outcast could no longer survive in the village. With feudal tenure, caste was still powerful as a common bond against unlimited oppression. Whole villages would desert en masse if the baron bore down too hard. Their caste-fellows were bound to help these peasant strikers in distress. Further, the village need for a potter, blacksmith, carpenter or barber was fulfilled by artisan castes when the level of commodity production was low.

Today, factory production, overcrowded cities, road and rail transport have changed all this. Caste persists only because some people gain from it, namely, those who possess land, hold the priesthood, and so on. Caste disabilities persist in spite of legislation and-in many places-mass conversion as to Buddhism. The root cause is the abysmally low economic status of the lowest castes and their total lack of opportunity. Neither legislation, nor conversion, nor schoolroom education can remove this. The sole possible cure is more efficient production and distribution of the product in a manner equitable for all; most people call this socialism. But equality on paper and the adult franchise will not be enough, when politicians can use caste for vote catching and distribution of patronage.

To take an allied but smaller point: most economists see no future for India without birth control. The national income and production are not rising at a faster rate than the population, so that the net gain is virtually nil. But why do people want children in a poor country? The usual answer is, 'superstition'. A son is essential so that the parents may go to heaven and be given the annual oblation to keep them there.

Silly as this is, it contains an ancient historical truth. Archaeology tells us that it was a tremendous and extremely rare achievement in the older Stone Age for any human being to reach the age of forty years. Food production instead of food gathering made it possible for a substantial number of people to live longer. This only meant that some people lived to an age where they could no longer fend for themselves and had to be fed by others as in childhood. The offering to the manes (*pinda*) is

simply an extension of this practice, when the ancestors have entered upon the long sleep of the grave.

If, now, birth control were by some miracle enforced, it would mean that every person who reached a certain age and physical condition would have no one to feed him in the present social set up. Children are necessary precisely because Indian parents have no other means of subsistence in old age. Insurance, savings, landed property, pensions or other means of income would not suffice, at a guess, for as much as five per cent of the population. So, the birth control expert is in fact asking people to starve to death in old age so that some other people will be better off.

Most of us are not likely to listen to the argument. Where food was very scarce, e.g., in Rajasthan until the last century, a dreadful form of population control was affected by female infanticide. Today, population control will be successful only if people are convinced that there would be enough for them to live on in their old age even if they have no children.

The real stupidity lies with the ‘planners’ who try to regulate the total numbers of the people by theory, without assurance of a reasonable livelihood for the people in existence. The expert who talks of epidemic and famine as natural checks upon the ‘population explosion’ himself runs to consult the doctor the moment he has a fever; and never goes without a full meal if he can help it. There are modern superstitions in the guise of science, quite as deadly as those of religion.

The need is less for reform or even the abolition of religious superstition than for basic changes, which can only be described as revolutionary. Unfortunately it is possible to have a revolution without its promised benefits, but never the benefits without a revolution.

6.SIN AND SCIENCE: INTRODUCTION

Every person who has reached social maturity in a modern city can say that the meaning of crime, sin, and science is self-evident. Most of us, in India at least, know that sin depends upon the particular religion professed; drinking wine is a sin for a Muslim, beef eating for a Hindu, while the Christian does both without a qualm. This variable concept of sin being no longer sufficient to regulate society, legal sanctions are applied to forbid certain actions which are labelled as crimes, to be punished by police and court action. A crime must be detected and the offender put through some-legal formalities before punishment becomes effective; retribution for sin can hardly be proved in most cases, hence is usually relegated to the next world or the next rebirth. For science, the consequences rest upon logical materialist interpretation of careful experiments or observations, independently of theological or juridical regulations. He who swallows a certain dose of poison must die whether the action is legal or not; allowing the proper number of bacteria to lodge in your system develops corresponding disease - whether God wills it or not-with a definite statistical frequency.

If now all three of these approaches tell us the same thing, if the commision of sin should lead to a strong possibility of disease while being also a crime, society then seems to be doing its best to stamp out a dangerous evil. This is certainly the case in the regulation of sex-relations, with its concomitants: divorce, venereal disease, prostitution; similarly for drunkenness and its effects upon the individual, upon his family, and upon society as a whole through increase of accidents in a machine age.

Dyson Carter reports fairly and dispassionately upon the methods used quite recently to stamp out these evils in two entirely different contemporary civilizations, each a leading model of its own type. In the USA no one can deny the powerful development of science, with an even more powerful development of the police force; all American religious groups combine their efforts upon such questions. Nevertheless, the divorce rate is increasing, and is about the highest in the world; venereal disease, prostitution, alcoholism remain ineradicable spite of ‘reform’ political campaigns, special police drives, and constant exhortations from the pulpit. In the USSR the first and greatest representative of a new form of society, there was every reason for these deadly byproducts of modern society to have hared up. Organized religion was smashed by the revolution, most former restraints removed, the prostitute no longer punished as a criminal, divorce made almost effortless, and cheap liquor provided by the Government. Add to this the misery of wars of intervention following the revolution and the constantly increasing rate of production; then, bourgeois logic would lead you to expect a continuous debauch. Yet, we find that prostitution has disappeared altogether, the divorce rate forced down to a negligible level, drunkenness now almost unknown in a country once notorious for its besotted muzhiks and workers

These results, which might seem paradoxical and even fantastic, were obtained simply by turning scientific inquiry upon the sorts of the problem, following its conclusions to their logical end. What the policeman dare not, priest cannot, scientist does not ask in capitalistic countries is why the social evils exist at all. The Soviet answer is that they exist because certain classes of people make heavy profits thereby. The exploitation of vice is a simple consequence of that general exploitation of the vast mass of people, which necessarily drives a considerable number to vice. Removal of the general exploitation took away the prime cause, and ruthless punishment was served out to those who tried to make profit, not to their victims: to the brothel keeper, not the prostitute; to the bootlegger, not the drunkard. At the same time, the right to employment became part of the way of life, a decent livelihood being made possible for all. Then it was easy to observe the effects of the new freedom, to turn on legislation, party propaganda; scientific education of the people. Alternative forms of amusement and relaxation had been provided for all with full literacy and cheap as well as good reading matter, fine music, excellent cinema, parks of culture, sport. The former evils disappeared simply because they no longer had any reason to exist. Life became so well worth living for the first time that escape from it was no longer necessary.

We face the same problems in India and are now trying the American system, including prohibition. However, any profiteer is free to shorten the lives of his countrymen by denying them the essentials of life and. he does this as member of a highly respected class. The police protect him and his gains against the victims. The scientist ignores the effects of starvation, filthy lodging, lack of education upon those who made the profit possible, and rushes to help the capitalist with technical advice, medical aid, or even gratuitous praise; for who but the rich can pay well, who but those who have made heavy profits endow research? As for religion, it merely proclaims that the oppressed will get their due in some other life or still more comfortingly that they must have misbehaved in a previous birth to suffer so now; that is, they may be ignored altogether or squeezed even more painfully. The reformer, with the best of intentions, attempts to gain the benefits of a revolution without the revolution itself.

7. REVOLUTIONS AND TEE PROGRESS OF SCIENCE

It is believed by many that the purest forms of thought and their expression can develop as according to Bourgeois social theorists - only during periods of peace, quiet and plenty. This might seem reasonable, in view of the fact that whereas “purely utilitarian” sciences like chemistry might be developed by the order of the state and a crying emergency, the abstract sciences like mathematics can hardly be pursued by decree. As a matter of fact, this point of view is superficial: there are no purely utilitarian sciences, and discoveries in the most abstract of sciences can be traced to some perfectly material need of the time, or to some expression of the structure of existing society. But instead of developing this thesis, I shall consider one “pure” science, Mathematics, and its recent development in some countries where it might reasonably have been neglected in view of the objective circumstances.

Mathematics Amidst Spanish War

I have a letter from Madrid, dated May 12,1938, to the effect that the Spanish Mathematical Society regrets the fact that certain volumes of the Indian Mathematical Society's publication (received by them in exchange) are missing from their files, would we be good enough to supply the lack, and receive in exchange whatever issues of their journals might be missing from our files? (Till the summer of 1938, their publications reached us with regularity, were sent as from Madrid and apparently printed in Madrid). No mention has been made in the letter cited, of the Civil War or the difficult times; one would be hard put to it to guess anything out of the way from the letter itself except for one thing: the sheet on which it has been typed was cut off just below the signature, presumably to save paper. "Business as usual" seems to be their motto; whenever possible, they want to do it better than usual. Since Gerbert (supposedly) received his training there from the Arabs about a thousand years ago, Spain has not led Europe in mathematics. With the Republican movement, foreign mathematicians were occasionally invited to lecture in the university. Two years ago the first excellent *original* mathematical work appeared from a Spanish pen, the *Geometria Integral* of Santalo. And if the war does not end in the complete annihilation of the Loyalists, we might reasonably expect more to follow.

To match this, there comes a letter (Sept.7, 1938) from Hong Kong, from the National Library of Peiping, which has temporarily established an office in British territory. They too want our publications but the war and the hard times are explicitly mentioned: "As many of our universities and scientific institutions have been deliberately destroyed by Japanese militarists, the need for scientific literature felt by Chinese scholars is most urgent". Yet, the Chinese look to the future, and frankly ask for help in a time of desperate need. The Chinese Mathematical Society had just been born when the war broke out, and I have been unable to get in touch with the editors of its publications, which have probably ceased by now.

Soviet's Place in Mathematical Research

The question naturally arises, how is it in a country where the revolution had not a "democratic" aspect as in Spain, nor a national one as in China, but where the Bourgeois element was crushed and uprooted by the iron will of Lenin and his successors? What happened to mathematics in Russia when Russia itself became the USSR, and some portions were actually separated by external force or by secession of national minorities? How does the Russian school of mathematicians compare with others? The consensus of opinion is that as a school, the Russian takes no less than the second place among national mathematical groups, the first being assigned to the United States of America. Judgment, of course, is on the basis of published works alone, and merit as well as the total output of research is considered. Here, it must be mentioned that by current Indian standards, only Cambridge (England) exists as a center of mathematical achievement, and the supreme achievement possible in mathematical fields is to have obtained a degree at Cambridge, preferably by passing an examination, which is considered superior to any research degree.

Part of the mathematics in Russia is inherited from Tsarist days, and the tradition is really old. Catherine The Great imported the best that Europe could offer, and from the year 1826, when Lobachevsky published his epoch making discovery of non-Euclidean geometry, native genius might be said to have matured. Yet, the names are few. Chebyshev, Liapunov, and the startling Sonia Kovalevskaya. After the entire mathematician was indubitably a bourgeois since revolutionary activity and research could hardly have been compatible. We do hear of one Linde, mathematician and philosopher, who "saved" the revolution in 1917 by calling out the Red regiments on the streets of Petrograd in April, but I am not aware of any mathematical discovery or theorem that goes by Linde's name. A few of the best found jobs in other countries, and we notice Besicovich in England, in fact at Cambridge, Tamarkin Uspensky in America. They are among the leading lights on the subject in the countries of their choice. Others, like Alexandrov, and Krylov, have stuck to their posts, and developed into world adthorities on their respective subjects. Alexandrov, in particular, specialises in the most difficult branch of the whole of mathematics, Topology.

The burden of bringing distinction to the new proletarian state rested on those who remained, and upon those who learned from them. There has been no doubt at all that those who remained have been encouraged to do their very best, and have had whatever comforts were available in the lean days of the civil wars and the first five year plan. 'Their productivity has greatly increased, which does not imply a dread of the G.P.U. for sabotage, but decent treatment, intelligent students-a most important stimulus for the research work of those whose profession is teaching-and a certain amount of enthusiasm for the progress of their country. But is this legacy from older days in danger of dying out under the dictatorship of the proletariat? Does the wiping out of the Bourgeoisie from which they were recruited imply that they will have no successors? Will the five-year plans create engineers and statisticians to the exclusion of mathematicians as such?

U.S.S.R, Ranks Second in the World

The answer is very pleasant to any research worker. The outstanding work which places the "Russian" second in the international scale has been performed to a considerable extent by new and locally trained men, in distinction and contrast to that of the American school, which has gained recruits from all countries of Europe for hard cash, profiting in particular from the treatment of distinguished non-Aryan scientists in modern (since 1933) Germany. Imported, scholars are a rarity in the U.S.S.R, and with the exception of a very small number, (the Polish Jew Walficz, for example at Tiflis), negligible in quality.

To name a few outstanding performances, we have the work of Vinogradov in the analytic theory of numbers. Till this giant of analytical technique entered the field, the work of Hardy, Littlewood, and their pupils in England, with that of the late Edward Landau and his students in Germany was considered the limit of modern mathematical achievement in the theory of numbers. As a result, several important problems were practically insoluble. Vinogradov's results are based on his own refinements of the estimates for trigonometric sums, and in the last five years, this work has led him to the very top of his branch of the subject. Waring's problem can be regarded as essentially finished due to his efforts, the very best estimations in the distribution of prime numbers and of the zeros of Riemann's zeros function, derive from his work and that of his pupil Chudakov. And now, and his latest, we have what amounts to a settling of the famous Goldbach conjecture. The Waring and the Goldbach problems have occupied the best mathematical brains of the last two centuries, but the end was brought in sight only by Vinogradov.

To give only one other example, we note the fact that another half-century of mathematical endeavor was rounded off in 1934 by Kuz'min and Gelfond, who probed the very basis of the concept of real number, and settled a problem proposed a generation ago by one who is still regarded by many though long past the age of scientific discovery as the world's greatest living mathematician, Hilbert (German). Briefly, any rational number except zero and unity, raised to any algebraic irrational exponent is a transcendental number. It was known before, that the transcendental numbers could be regarded as much more: numerous than the rational or the algebraic numbers but very little else was known about them.

Backward Nationals March Ahead

But this is not all. Among the mathematical papers written from the USSR, we notice names of nationalities, which could hardly have been thought of as capable of scientific work under the Tsarist regime. Razmadze died, but his work on the calculus of variations will live, and even the posthumously published memoir (1934) on Delaunay's problem of conjugate points, would, by itself, be a creditable performance for any worker on the subject from its initiation to the present day. We notice other Georgian names: Kupradze, Gogoladze, and so on. There is already a mathematical institute in Tiflis; papers of a respectable

quality appear there. The achievement would be comparable to that of producing research workers among the Pathans of our frontier province, and a really learned Society at Peshawar. The cultural level of the Georgians under the Tsar was certainly not higher than that of the Pathans to day. It might be argued that a Georgian being at the head of the USSR would give a tremendous impetus to all kinds of advance in Georgia, but the reasoning does not hold. Turkey has nothing to show in comparison, and there is nothing like an Irish school of mathematics, although president Dr: Valera is admitted by his biographers to be very well acquainted with mathematics of the 'pure' and 'higher' variety.

To be quite fair, one would have to consider post-war mathematical advance in other countries as well But the present ranking given to the Russian school, which certainly had no rating at all at the time of the revolution, speaks for itself. Neither that estimate of the whole " Russian " school of mathematicians nor the appraisal of the individual efforts cited is my own; I have been careful to quote from the opinions advanced by bourgeois European and Americans who were acknowledged authorities in the subjects themselves, and who, in the cases known to me personally, are violently anti-communist. I have no reason to subject any political bias on their part in favor of the "Russian" scientists.

Progress in Poland

In those countries which were carved out of Russia by 'national' revolutions only Poland can show any mathematics, and this is remarkably sound though limited in its scope. I have not mentioned the innumerable mathematical topics to which valuable additions have been made from post-revolutionary USSR; Statistics, (Khinchin, Kolmogorov) for instance, is one; and I mean the mathematical theory underlying statistics, not the mass of figures that make up the average man's notion of statistics. The Poles on the other hand specialise in Topology, and real variables. But the outstanding achievement is the discovery which lies outside both fields, by Lukasiewicz (1920-1931) of polyvalent non-Aristotelian logic: logic in which the excluded middle can appear, i.e. in which propositions need not be either true or false. This is a fundamental discovery of the first magnitude, but an individual effort. The productivity of the Polish school as such (add enthusiastic participation by national minorities) cannot be compared with the achievements across the border. The other countries need hardly be mentioned, though an occasional individual might exist (Nevanlinna in Finland.)

Mathematics Under Fascism

As compared to this, things are not so well with the Fascist Powers. Germany has pushed out its non-Aryans and therewith, a great deal, apparently the greater part, of its mathematical talent. The unfortunate repercussion of this exodus has been that the ablest have found good jobs in other countries, and so brought about at least a tinge of anti-Semitism in the academic circles of the: various lands of refuge which saw their own local products going jobless. Italy, for instance, which possesses the dean of living differential geometers in, Levi-Civita, is developing Aryan tendencies, and if they become at all serious, this veteran might see the country to which he has brought so much scientific distinction during the last thirty years become a land of misery during his old age. The theory of relativity and set-apparently unrelated a subject as also dynamics are both based upon the absolute differential calculus which he developed in conjunction with his teacher Picci, and of which he is perhaps the greatest living exponent. The Fascist revolution found at least one famous mathematician among its enemies, Vito Volterra. But surprising as it may seem, he was allowed for years to continue unmolested, and to vote against the Duce's measures in the Italian senate, which he did with futile but monotonous regularity. To elate, mathematics in Italy has not shown the heavy decline in standard that it has manifested in Germany, but with Aryanization, we might begin to see Ersatz-

mathematics too.

In the third, prominent member of the anti-comintern league, i.e. Japan, we do see mathematics still on the up grade, and Takagi, plus the Japanese school of differential geometers headed by Kawaguchi, are outstanding recent phenomena. I take it that in Bourgeois Imperialist forms of national development, the cultural elements lag behind economic advance or retreat and that mathematics in Japan, reached the level there attained by directly to industry, is still expanding. In as much as I began this note with quotations from letters, let me finish with one from a Japanese mathematician of international repute. I had wished at the end of a technical letter, as a matter of courtesy, that the war might not affect his work adversely. He replied "...Here in Japan, there is no disturbance of public and economic peaces and our life as well as our labour is just so as the past. It is very sorry for the peace of the world, there are many false reports on the present Japan-Chinese affair which let peoples of the world misunderstand the righteous and peaceful object of Japan [Amazing! Ed.] and which have danger to the whole world in a great war. These reports seem to be marked in accordance with the political and economic policy and accordingly to stop the development of the oriental nations. But after the glorious victory of Japan the truth will become clear."

I give the quotation for what is worth, without other comment than that the author is a particularly competent scientist, and as alert a person in his own branch of mathematics as can be found anywhere today, to the best of my knowledge, no one in USSR (which is mathematically far ahead of Japan to day) can touch him in his own field. The letter is dated November 4, 1937, and we have not discussed anything except mathematics in our subsequent correspondence.

Conclusion

The conclusion is irresistible that even the purest of pure science flourishes at its best when it develops in harmony and sympathy with its surroundings. A revolution, which is attended with the greatest objective difficulties and is carried out in an unfavorable external environment can, even then, act as a stimulus to research. Our students are invariably told that any sort of political activity will interfere with their studies, and that culture can only flourish in an atmosphere of quiet. A considerable number of convocation addresses could be found holding up the sad example of intellectual destruction in Russia. The facts however, do not bear out these contentions. Our country has produced only one mathematician of the first rank after Bhaskaracharya eight hundred years ago. This was Ramanujan and he was unable to pass even the first year of college. India gave him birth, starvation, tuberculosis, and a premature death. It is to the everlasting credit of the English mathematician Hardy that he recognized the merit of one who was considered half made by the Indians, had him brought in England, trained him, and brought out his splendid ability. But there has been no one here who built upon the work of Ramanujan and by influence, Ramanujan is to be regarded, as an English rather than as an Indian mathematician. Our tradition is still one of passing examinations here and then repeating them in England, not of doing anything new. It is Hardy's considered judgment that irreparable harm was done to Ramanujan by the misery and destitution of his formative years-from the age of seventeen to twenty five; the unchanged educational system, coupled with the philosophy of living as well as possible on the droppings of the Imperial administration will, in my own opinion, continue to do the same to any lad of genius.

8. SOVIET SCIENCE: WHAT CAN IT TEACH US

We ape met here to celebrate the rise of a new movement of the utmost significance for India, and hence for the world: Friendship for the Soviet Union, based upon a study and understanding of soviet Culture. I take for my topic to day, one aspect of this culture, Soviet Science.

The questions that arise immediately are: Is there any real science in the USSR as judged by international standards? Could we, in India, possibly get any benefit from it, seeing that we do dot know Russian, and do not use Marxist terminology habitually? Finally, if all these questions are answered satisfactorily, we shall have to ask: What is the basis for the emergence of this Soviet Science?

Applied Science in U. S. S. R

In Engineering, Soviet preeminence cannot be doubted. The gigantic successive five-year plans had, as their basis, tremendous feats of engineering in the USSR. Although foreign engineers were imported at first to speed up the tempo, the work has been done, and has been very well done for the last decade or more by Soviet engineers entirely. All this does not have to be proved. You saw in 1941 the sudden attack upon the USSR by a highly trained, beautifully equipped army that had swept all the great armies of Europe out of the field. But to day the USSR is stronger than ever before while the German army of 1930-41 is only a memory. The credit is due in the first instance to Soviet morale, backed by Soviet production, and based upon Soviet advances in Science.

Soviet geologists, the finest in the world and the most numerous of any band of geologists anywhere, opened up the immense resources of the Asiatic hinterland of the USSR. As a result, the productive basis was shifted to a center beyond the reach of Hitler's best bombers. New cities like Magnitogorsk sprang up, and the barren steppe began to vibrate with a new life. ***Tsarist Russia, like British India, was subject to recurrent famines. In 1919-20, with the worst of these famines raging and intervention plus civil war destroying the resources of the country, Lenin proposed that funds should be set apart from those allocated to famine relief so that scientific institutes could be set up in order to make future famines impossible.*** **This was the beginning of the great research institute now headed by Vavilov. New cereals and grains were produced, but not merely by tilling fields. The Soviet biologists went to the remotest corners of the earth, Abyssinia, and the Andes, to collect plants, They were studied in the laboratories, acclimatized in the USSR; new theories of genetics arose, connected with the names of Vavilov and Lysenko, and additions to Darwinism were intensively developed in the USSR, as a matter of the utmost practical importance; scientific controversies were productive of new discoveries. Hitherto, potatoes could not be improved because of the unsuspected fact that they all belong to a single Linnean species. The Soviet expedition to the Andes found thirteen new species, and produced superior varieties by cultivation, selection, and crossing. A new wheat was produced that call give as many as three crops at one sowing. New cottons have been developed; Gurvich came out with a new theory, still undecided, about mitogenetic rays that promote growth while they are too feeble to be observed by the usual physicist's methods.** ***Other countries looked with suspicion at all these discoveries, because the scientist never stirred out of his laboratory and because the problem in those countries was not increase of production but increase of profit regardless of who was fed and who was not.*** **In the USSR, science went ahead on all fronts, its features being long-term planning and cooperation. The USSR has no rubber trees. A trifling producer is the wild** ***Kok-sazuz*** **plant of the Caucasus. This was intensively cultivated, and then Soviet chemists produced synthetic rubber from potatoes and other agricultural products, using the rubber successfully, long before German production had got into its stride. By contrast, the countries of free science are now finding the need for planned science. The USA receives some rubber from the Firestone monopoly in Liberia (which incidentally ruined what was left of freedom in that Negro**

republic), but has had to build synthetic plants. The British empire has only Ceylonese plantations to fall back upon, and those are in poor condition because of the restrictions put upon rubber production to keep up the profits first of the British and then of the Angle-Dutch cartels. Synthetic production in Great Britain is possible, but not very likely because of the conflict between the profits from the manufactured and the natural product.

Great Strides In "Pure Science"

I know that some critics will dismiss all this as applied science, putting all their faith in "pure science". They will say that no pure science exists in the USSR. That is drivel, or propaganda. ***In the first place, the greatest researches in pure science arise from some deep social need, or remain sterile.*** **You will recall the fate of Leonardo da Vinci who, in the 15th century, exercised his universal genius by making or at least imagining dying machines, war tanks, great engineering schemes, and profound scientific observations. To be effective, however, every one of his discoveries had to be made by some one else, and so reintroduced to the world. Leonardo's own genius was sterile because human society in his day had not advanced to the stage where it could do more than admire the beauty of his paintings. His years of service were spent in designing ballets and palace ornaments for minor Italian princelings, as a parasite upon a parasitic class.**

To come to pure science you all know, or should know that India's greatest discovery in modern physics, the Raman effect, was made independently and several months before Prof. C.V. Raman announced it, by two Soviet physicists, Landsberg and Mandelstam. ***This does not detract from the merit of Sir. C. V. Raman's work, but it should prove that the Soviets are in the front rank of physicists.*** **Kapitza was Messel professor at Cambridge, till the Soviet authorities decided that he should spend all his time in the USSR, thus raising angry squabbles. But the point is forgotten that a special institute was built for Kapitza in the USSR, giving him every facility he could want, while funds were beginning to dwindle at Cambridge in spite of Rutherford's personality and influence. In the purest of all sciences, mathematics, when taken as a whole, the Soviet school is generally considered second, first place being given to the USA, but there are two striking contrasts.** ***In the first instance, the greatest names in American mathematics belong to those who emigrated from Europe because of Hitler's tyranny. Soviet mathematical research is a Soviet product, because the greatest Tsarist mathematicians got jobs outside the USSR, although offered every inducement to stay. In mathematics, as in other subjects, the USSR and the Soviet system produced still better workers within a single generation, while giving the maximum facilities to those who remained from the old regime*****. For this alone, if for nothing else the USSR would deserve the admiration of all impartial scientists. The second point, however, is still more important.**

While research except that directly applied to war purposes is being systematically shut down all over the rest of the world, even in the USA, it is being encouraged even more than before in the USSR. The Soviets do not want their scientists to die on the battlefield like Moseley, or to join inferior ministries in the capacity of useless and unused experts. The scientists are a national asset, like water, power and iron ore. Many have been allowed to join the artillery, which has thereby become the best in the world, but the best are asked to carry on in their own field, and to train others for pure as well as applied research.

What we can learn

Can we make any use of Soviet Science? The question really comes to this: are we in a position to make any use of any science at all? If so, we can utilize Soviet work to the same extent. Let us take a few examples to show that in fact use is actually being made in India of Soviet discoveries. This country needs quinine substitutes because malaria is endemic, and because most of the cinchona plantations that enabled us to export quinine at the end of the 19th century have been cut down, apparently by

government order, leaving us at the mercy of the Dutch monopoly which lost all its cinchona trees in Java to the Japanese. These quinine substitutes, familiar under the German names of atebrin and plasmoquine, were developed -in the early 1930's simultaneously in Germany and the USSR, with an important difference: *The Germans, working for companies, kept their processes secret, while the Soviet scientists published their own as soon as field work had proved the formula to be really useful*. Some Indian chemists have recently announced the preparation of these substitutes on a *laboratory* basis, when we need production by the ton; but all the work really derives ultimately from Soviet research, without acknowledgement.

Sadder examples can be given. I needed information on an Indian variety of *Phoseolus*, for some work on genetics, and asked a local professor of botany. He said that nothing had been done along those lines, that he had himself discovered an unknown wild variety near Poona, and that some day, when he got the time and the fat research grants he needed, he would write a paper on it. But in the fourth volume of the great Work published by Vavilov and his co-workers (Kulturnaya Flory USSR) I found all the information I needed, including that about the supposedly unknown variety at Poona. These varieties had all been systematically traced, cultivated on a fairly large scale, studied under the microscope, and in the published literature, of which I found a complete working bibliography given by the Soviet scientists in their search for useful grains *The sad part of all this is that the sole available copy of this splendid and authoritative work was one that had been presented to Prof. Birbal Sahni at Lucknow by Vavilov's Institute. Our experts get along without any such trifles!*

In mathematics, our favorite branch is the theory of numbers. From immemorial antiquity, India has seemed to be the soil where the subject has flourished best. Our one great scientific genius of recent times, the late Srinivasa Ramanujan, also showed a remarkable talent for this subject. But in the theory of numbers as such, we no longer lead the world, and have not for eight hundred years. Ramanujan had to go to England for what little training he got before his untimely death. And British methods, of the school of Hardy and Littlewood, no longer suffice to give the best results. *The outstanding figure in the entire subject today is I.M. Vinogradov, the leading Soviet mathematician. Using Vinogradov's methods as basis. Dr. S. S. Pillai, now at Calcutta, has materially added to India's mathematical luster by bringing Waring's problem to its virtual end.* If I may be pardoned for referring to my own work, two of my recent results in statistics were based upon the profound theoretical (and purely mathematical) researches of another Soviet mathematician of international fame, Prof. A. Kolmogoroff of Moscow. From one, I was able to deduce new laws for the loss of weight of metallic currency due to circulation; from the other, I was led to some valuable theoretical conclusions about the space of infinitely many dimensions, and results of immense practical importance are now being developed which should be of material assistance in the complete reorientation of statistics as we know it to-day.

We need surgery, and plenty of it in India, but haven't a single surgeon who can open the brain case without killing the patient. We had some three thousand and odd volunteers for the first Bombay blood bank, where the Red army received blood from millions of donors. Soviet workers on blood structure, like Chruschoff, are again the best in the world. Their brain surgeons have made fresh advances from a study of head injuries received in the war. The great surgeon Filatov has, alone, restored more blind men to sight than in the whole history of medicine before him, by his new technique of grafting a dead man's cornea upon a living eye. You must have read about cases of nerve grafting that materially hasten recovery of the wounded. I cannot believe that we have no need of such discoveries in the country. That a few well-paid pseudo-scientists announcing old Soviet results as their own discoveries (in India; this sort of cheating won't work outside) will not be all the benefit we can ever draw from Soviet science.

But to get greater benefit, we must have better contact between our younger scientists and the Soviet workers. Language

presents no difficulty as Soviet workers always append an abstract of their paper in some European language, with recent emphasis upon English; many papers are written and published in European languages, even in Soviet publications. What is missing is the means of communication. Before 1939, scientific journals were received, though late and not always in a good condition. Since 1939, there has been almost no contact, and matters have not improved after the alliance between Great Britain and the USSR, so far as India is concerned. You can find your own reasons fell this.

What Explains Soviet Progress

What is the basis of Soviet advance? Is it a Soviet phenomenon, or just a national Russian resurgence? One section of British science who graces the Indian Medical Service in this country, announced proudly to the medical section of the Indian Science Congress that all Soviet advance was in reality a nationalistic advance, due to the total abandonment of Marxian doctrine and even of Socialism. It would surprise a Georgian scientist, and many of them who have learned since 1917 while there was hardly one before, to learn that his research was based upon Russian nationalism; it is like saying that the Pathan are good scientists (if there were any Pathan scientists) because of the caste system. Vavilov and Lysenko are both very good Marxists. So good that even J.B.S. Haldane came over to Marxism and discovered its fundamental uses in science, saving himself a great deal of wasteful effort. The Marxism, however, operates in another fashion apart from the philosophical implications of dialectic materialism through the social structure of the USSR. This social structure is also fashioned by the world's best Marxists. All nationalities are free to participate in science; and encouraged to undertake research. The basic education is in their own and not in some foreign language. Women are welcomed as research workers in every laboratory, and they are heads of some important ones. This does not mean, as in India, some reserved jobs for members of statutory minorities, or a "Brahmin-Non-Brahmin" quarrel or a "Hindu-Muslim" question in educational circles of the USSR. These questions are intimately connected with the growing middle class of India under foreign domination. In the USSR, there are no classes, and no foreign rule. All are free to follow their natural bent, and the utmost is done to develop that bent by universal free education. The one freedom that is missing is the freedom to starve, and I may suggest, very humbly, that as long as we rejoice in that particular freedom in India, to the exclusion of all others, we shall not be able to utilize Soviet or any other science for progress and happiness.

9. NUCLEAR WARFARE: THE REAL DANGER

The question of nuclear warfare, the continued preparations and testing of completely new types of weapons is literally the 'burning' question of the day in international affairs. Everyone is aware that such warfare could destroy all life on earth, not only human life, if every nuclear weapon in existence today were set off at once. The annual expense upon these new weapons is generally a guarded state secret, and carefully disguised under other heads in every state budget. Nevertheless, two facts are clear. First, the total annual expenditure upon nuclear arms alone exceeds that for all conventional weapons in the whole world before 1939. Secondly, if this expenditure and some of the supplementary expenditure on conventional weapons could be utilised for helping the underdeveloped countries, we would all be able to live a happier and far more comfortable life. That is, non-participants in the power race would be free from the feat of sudden annihilation because someone pressed the wrong button ten thousand miles away. The new factories, mines, roads, machines, hospitals, schools and so on would make life more comfortable. If the power-blocs do not want to spend this amount upon the more backward parts of the world, nothing can compel them to do so; but surely, there are plenty of people who have not enough of this world's goods in the USA, Great Britain, France or Russia even by the standards these countries set for comfort. No one would object if the arms race were turned inwards to a race for higher standards of living if all the hospitals, schools, etc. were built only in these four great countries, which have atomic weapons today. For all that, nuclear warfare is being prepared for an ever-mounting tensions. Before 1939, eminent statesmen all over the world were declaring publicly that a second world war was in the offing. It did come, because or in spite of the efforts of these eminent prophets. Why are both sides now preparing so hard for something so much worse? Is it really so much worse, or is the danger greatly exaggerated?

It is not my purpose to go into scientific detail, which would only drown the issue in a fog of technical terms. Neutrons, electrons, gamma mesons, pi-mesons, alpha rays, gamma rays, the structure of the nucleus, the critical mass, Plutonium isotopes - you can read all about these in any number of scientific and popular expositions. Nuclear weapons are much more dangerous to use than the conventional, such as bullets, bombs, shells, and even poison gas. The record number of deaths from a single conventional bomb was during the Japanese invasion of China, when an aviator unloaded in a desperate effort to save himself and killed nearly 700 people who had crowded the streets of Shanghai to watch the dogfight in the air. 7he Hiroshima bomb killed about a thousand times this number. A 50-megaton weapon could wipe out the largest city in the world with its suburbs, causing from 8 to 15 million immediate deaths. In addition, there is the question of side effects, the nuclear fallout. In 1954, the weapons available if dropped on Delhi when the hot winds were blowing, would not only have wiped out our capital, hut would have killed every living creature and damaged all vegetation within a belt 150 miles wide, stretching from Delhi to beyond Calcutta. You can calculate the damage for yourself. There are much powerful weapons now.

Under these circumstances, why is the Geneva conference dragging along month after month, year after year? Eminent scientists at the conference and elsewhere have said all that has been said here and have driven their points home with scientific proof. Still, the agreement is as far off as ever. So, let us examine the arguments that still appear in a section of the press for: keeping the weapons, for not agreeing to a total ban, and for continuation of tests and counter tests. These arguments may briefly be taken as: 1) Thermonuclear weapons are the ultimate deterrent. 2) Science and the scientists are in some way responsible for this fearful engine of destruction. It is their insistence that compels the governments to carry on at so heavy an expense; atomic weapons will in some way advance scientific knowledge and eventually help mankind. 3) The danger is greatly exaggerated. Fallout is not so bad after all, for all we may know; there may be beneficial effects. Continued testing will bring out these effects.

Let us examine these arguments, of which the first is political in content, and the rest at least look like the common man's idea of science.

1) The Ultimate Deterrent: To deter means to prevent someone from taking certain action. Here, we are told that if the Russians attack they are sure to be wiped out by a counterattack. To make the counterattack effective, new weapons and new methods of delivery must be perfected, hence the need for trials. The very fact that the Russians have not attacked is supposed to show the effectiveness of this sort of preparation. This last bit of logic is on a par with bathing on Chowpatti beach to free the sun from an eclipse; the fact that hundreds of thousands of people do so and that the sun has always been freed from its eclipse should prove that such ritual baths are necessary in India, though other countries manage without them; yet we Indians are blamed for being a superstitious, backward lot for these innocuous pastimes! However, the Russians clearly refuse inspection, though they are free to inspect the other side's territory on equal terms. Is this not evidence of malice and evil intent? As matters stand, no! If you can knock out the other side's launching pads and bomber bases first, then you can bomb his cities without danger of retaliation. To do this, you must have two qualifications. First your stockpile of weapons must be great enough to saturate all launching sites and attack positions with enough left over for the cities and big targets. Secondly, you must have accurate knowledge of the enemy's launching sites, which are always carefully hidden, and well away from

population centers. If inspection allows these sites to be inspected by the other side, and the other side has overwhelming superiority in nuclear weapons, the temptation to start a preventive war becomes irresistible. It can always be claimed afterwards that the war began by error, by someone pressing the wrong button without authority. So, the deterrent' when there is no inspection is really the stock of weapons possessed by the weaker side. It will deter only as long as their launching sites have not been revealed. At present the weaker side in stocks of nuclear, weapons is definitely the USSR. They started late in the manufacture of atomic weapons. Their industrial potential is less than of the USA alone, and much less than of the western allied combined. Also, they had for greater war damage to repair, without outside help. The superiority of the USA to the USSR in nuclear weapons should not be less than 10 to 1, and may be as high as 30 to 1, unless there has been some remarkable wastage and swindling. On the other hand. Russian rocketry is definitely more formidable. Though they have no ring of sites around the USA as the Americans have around the USSR, they could certainly retaliate effectively no matter how many of their cities were knocked out, provided their missile bases are not pin-pointed. In the event of atomic war, they would have to move out of their own country for mere survival. This raises interesting possibilities, namely that, instead of deterring, the atomic threat may actually promote invasion after thermonuclear war has started, or is known to be on the verge of starting. No Soviet statesman could possibly confess openly this position of inferiority without difficulties at home. The only solution is an immediate ban on tests, destruction of the means of delivery, gradual conversion of stockpiles, and inspection by modern instruments in sealed packages set all over the world, without on-site spy teams.

2) Science: The scientist is taken as the great offender and sinner in developing these weapons. This is piffle. No scientist has the billions of dollars needed for such developments. Those who supply him the dollars (or pounds, franks, roubles) do so for a specific purpose; if the scientist does not fulfill that purpose, he loses his job and perhaps his freedom and his head as well. The funds spent upon the development of nuclear energy are primarily taken up by engineering problems and the purchase of raw materials, not the advancement of science. There will not even be some accidental promotion of science as a byproduct. Science has progressed only by constant international cooperation and interchange of ideas. Oriental science, particularly medicine, lost the advantage of an early start because useful discoveries were kept secret. The rapid advance of European science and technology derives from publication of results. The main pride of a real scientist is priority of some fundamental discovery published under his name. In thermonuclear research, all discoveries of any importance are kept secret, under the watch of politicians and militarists whose knowledge of science is hardly sufficient to estimate the gain or loss to the world of science. Thus, only opportunists or third rate scientists will allow their time and energy to be monopolized by research on nuclear weapons. Science requires controlled experiments. The thermonuclear explosions for testing may be controlled but their side effect, the fallout, is definitely not under any human control. There is no 'clean' bomb. The argument that tests have to be continued for the sake of science in order to produce a really clean bomb can be believed only by the cretins who put it forward.

3. The Genetical Danger: This is the real danger, the 'danger to generations as yet unborn' that we hear a great deal, but which is never explained. All radiation causes damage of some sort to the living cell. In some cases, under proper control, this damage can be utilized to kill cancer cells, for example, while the healthier parts of the body manage to recover. No one in his senses claims that unlimited nuclear testing and atomic explosions will reduce cancer or any other disease in the world without damage to healthy humans. The idea amounts to burning down a house and inmates in order to roast a pig. For human beings in the mass, an atomic explosion may kill by the heat and blast, to the extent of vaporizing the human body. It may kill by the shock

wave. The ordinary TNT bombs do as much. The indirect effects such as collapsing or burning buildings etc. are the same; though the TNT bombs are measured in tons while modern thermonuclear bombs are of megaton size equal to millions of tons each, if measured in TNT. The effect of the radiation, however, is something the conventional bombs lack. The radiation may kill quickly by damage to the bodily cells, or lingeringly by damage to the bone marrow. If we admit war and killing as permissible methods of settling international disputes, and condone the slaughter of civilians, there is so far nothing to object in all this. The death, whether by a bullet or a conventional bomb or an atomic bomb, is death just the same. As for the distant effects, the Bengal famine of 1943, a concomitant of the great war, killed at least as many people as any thermonuclear weapon could by its side-effects. A cold-blooded view of killing in general can shrug this of lightly.

The findings of very competent scientists in the one country that has experienced the effects of nuclear radiation upon human beings-Japan-have not been better publicized, at least in English. The reports of effects upon atmospheric radiation day by day before and after nuclear tests; the radioactive matter contained in rainfall etc. are all measured and published regularly. Far more impressive is the thorough check-up and follow-up of every known survivor of Nagasaki, Hiroshima, and the Fukuryu Maru sailors. For some reason that escapes me, the Indian report on the effects of such radiation has carefully ignored the striking mass of Japanese material, even the careful summaries published in languages other than Japanese. The genetic danger is made clear by studies of children born to women exposed at Hiroshima, though they were not pregnant at that time. Some of the published, pictures are enough to give anyone nightmares.

Unfortunately, even this does not bring out the deep underlying danger. These abortions mentioned above are not fertile. They do not breed. They are often; till-born, and in any case die. Most of these strong changes are lethal. The troubles come when many small changes accumulate, the so-called recessive genes. We know of this because of innumerable experiments on the banana-fly, which has a life cycle of some 11 days. The experimenter can irradiate the eggs, breed several hundred generations, and live to publish the results. In 1951, some American work on mice exposed to heavy radiation was published. The mouse has a longer reproductive cycle and breeds for a longer time. The derangements of heredity have longer time to mature in a mouse.

They act on a decidedly more complicated bodily and genetic mechanism than in the case of the fly. From the mouse to the man is a correspondingly longer step. Here we have to guess, to extrapolate. It is known from the two cases of *Drosophila* and mouse in which direction the changes lie, and to what extent the life cycle and complicated cell-structure are responsible for greater effect. The total result is horrifying. There is no argument possible that some changes after all may be beneficial, that there can be no harm in fallout due to testing. Dr. Teller insists that wearing trousers will cause more mutations (in males only) than such fallout; a statement for which there is no evidence whatsoever. But in any case the wearing of trousers is not obligatory, the changes, if any are to the trousered males. With fallout, there is no choice; males and females will be affected in all countries. Still worse is that these cumulative effects will not be fully developed for twenty to fifty generations. By that time, they will have been bred into the entire human race, without discrimination of warring and neutral nations and without selection between communists and non-communists or Brahmins and non-Brahmins. There is no known cure for such changes; they are not diseases carried by infection, for example. So many hundreds of millions will carry the dangerous genes within their bodies that even brutal, cold-blooded mass extermination will not guarantee elimination or safety for the rest. Continued testing and insistence upon thermonuclear weapons is just gambling with the entire future of mankind. There can be no justification.

10. IMPERIALIS1M AND PEACE

We do not have, today; the peace yearned for by millions all over the world. In Korea we see a full-scale modern war waged relentlessly against an entire nation whose one wish, for centuries, has been unity, with independence from foreign aggression. In Malaya and Indo-China two decaying imperial powers struggle desperately to maintain the privileges of an outworn colonial system over the opposition of people who will no longer be denied freedom. Military operations in Greece, Indonesia, Kashmir, Palestine, have shown us for five years other facets of the same malignant activity.

Yet the supporters of peace have a power, which can stop this violence and bloodshed. For all these wars and acts of aggression - even the war in Korea - have been waged in the name of establishing peace. At first, we were given various mutually contradictory reasons why the Koreans were to be saved from themselves. Then we were told that General MacArthur meant to supply the aggressive leadership, which is all that Asiatics can appreciate. He seems to think that we Asiatics will naturally appreciate saturation bombing of peaceful villages, destruction of schools and hospitals, savage reprisals against civilians and prisoners of war. But this is an error. What we do appreciate is that his utterances show quite clearly who is the real aggressor in Korea. We Asiatics also belong to the human race; we also are made of flesh and blood; we tread the same earth, breathe the same air.

The peace we want means true democracy. The experience of millennia has shown us that no other kind of peace will last. No man shall claim to be another's master whether by divine right, the right of birth, the right of armed conquest, or the right vested in accumulated private property. Such rights can only be exercised by fraud and violence against the vast majority of the people, by destroying the very foundations of peace, namely, truth and justice. The lowest in the land must raise himself of full stature as an individual member of a great society. He must exercise in full, by actual participation in governing himself and others, his right to receive according to his needs, his duty to contribute according to his ability. Formal recourse to the ballot box for a periodic but ineffective change of masters will not suffice.

The stale proclamations of all imperialisms, from Rome to the present day, have again been proved false in the British, French and Dutch empires. The people of China rejected, in favor of democracy, the aggressive leadership of Chiang-Kaishek, who was so amply supplied with foreign arms and money. But the only lesson imperialism can draw from these rebuffs is that puppets are unreliable, that open intervention is a far better road to conquest - provided the other side is poorly armed. The Pax Romana and the Pax Britannica should now be replaced by a dollar peace, the Pax Americana. Tacitus gave a candid opinion of a contemporary Roman emperor: "He made a desert and called it peace." A modern historian might say of Hitler: "He waged total war, and called it peace." This kind of "peace" did not succeed in Europe, nor will it in any other part of the world.

Let us trace this crazy logic to its source. The issue of peace or war does not depend upon a single individual who is ostensibly at the helm of a nation, but upon the dominant class, which really holds the power. We are all convinced of the late President Franklin D. Roosevelt's liberalism and sincere desire for world peace. Yet in attempting to "quarantine the aggressor" in Spain, he only helped to destroy the democratic victims of fascist aggression. Hitler's advance into Czechoslovakia went unchecked, as did Mussolini's into Abyssinia, Japan's into. China. We can trace this kind of aggression right back to World War I and its aftermath, to the grim intervention against the young Soviet Union which had sounded the call for peace at its very birth. There is indeed a broad continuity of policy against peace and against democracy. This under-current has never changed its direction, no, matter what appears on the surface, Leaders like Mr. Churchill just carry out the interests of the

dominant class and would get nowhere without its backing; they are merely a symptom, not the main cause.

Look at another aspect of this underlying policy. Ploughing cotton back into the soil, burning up or dumping millions of tons of food into the ocean were desperation measures introduced at the beginning of Roosevelt's New Deal. Instead of changing the ownership of the means of production, or designing a better distribution mechanism, these transitional measures rapidly became a permanent feature of the American way of life. The United States government began regularly to pay subsidies to produce food, which was then destroyed to keep prices up. Up to 1950, American farmers were paid by their government to destroy mountainous heaps of potatoes and to feed to livestock wheat produced by the most modern farming technique; at the same time, Canadian wheat was being imported into the United States because even after paying the protective tariff, it was cheaper than the subsidized American product. This insane economic system shows exactly the same kind of twisted logic as that of modern imperialism which wages war in the name of peace and calls any move towards peace an act of warlike aggression, which bombs people indiscriminately to save them from communism.

The crooked roots of imperialism lie deep in the need for profits and ever more profits-for the benefit of a few monopolists. The " American way of life'' did not solve the world problem of the great depression of 1929-33. In the United States this was solved by War II. But only for a time, Korea shows that the next step is to start a new war to stave off another depression. The one lesson of the last depression, which stuck, is that profits can be kept up by creating shortages where they do not and need not exist. War materials are produced for destruction. Producing them restricts consumer goods, which increases profits in double ratio. Any logic that proves the necessity of war is the correct logic for imperialism and for Big Business, which now go hand in hand. Mere contradictions do not matter for this sort of lunatic thinking where production of food is no longer the method of raising man above the animals, but merely a way of making profit while millions starve.

Let us now consider the deeper fact that weapon-a negative weapon, but no less deadly bomb for bacteriological warfare. A bomb or a bullet shortens a man's life. The lack of proper nourishment also shortens a man's expectation of life by a calculable number of years, even when there is no actual famine or death by starvation. Deprive a man of food and you make him prey not only to hunger but to disease; do it year after year, generation after generation, and you produce a race whose minds and bodies are stunted, tortured, warped, deformed. You produce monstrous superstitions, twisted social systems. Destroying stockpiles of food is the same kind of action as building up stockpiles of atom bombs.

But the war waged by means of food is different in one very important respect from national and colonial aggression. It is war against the whole of humanity except that tiny portion to whom food is a negligibly small item of expenditure, war also against millions of American workers. In a word, it is class war, and all other wars of today stem from attempts to turn it outward. Even the Romans knew that the safest way to avoid inner conflict, to quiet the demands of their own citizens, was to attempt new conquests.

Quite apart the destructiveness of total war, the crooked logic of Big Business and warmongers is fatal to the clear thinking needed for science. The arguments that modern science originates with the bourgeoisie, that the enormous funds devoted to war research are a great stimulus to science, are vicious. The scientific outlook came into being when the bourgeoisie was a new progressive class, struggling for power against feudal and clerical reaction. Science is cumulative, as is large-scale mechanized production, which congeals the result of human labour and technical skill in increasing large and more efficient machines. But for modern capitalists, a class in decay, the findings of science (apart from profit-making techniques) have become dangerous; and so it becomes necessary for them to coerce the scientist, to restrict his activity. That is one reason for

vast expenditure on secret atomic research, for putting third-rates in control to bring big-business monopoly to the laboratory. The broad co-operation and pooling of knowledge, which made scientific progress so rapid, is destroyed. Finally the individual scientist is openly and brutally enslaved for political reasons. Science cannot flourish behind barbed wire, on matter how much money the war offices may pay to ‘’ loyal “ mediocrities. Freedom is the recognition of necessity; science is the investigation, the analysis, and the cognition of necessity. Science and freedom always march together. The war mentality, which destroys freedom, must necessarily destroy science.

The scientist by himself can neither start nor stop a war. Modern war has to be fought by millions in uniform and greater numbers in field and factories. But a scientific analysis of the causes of war, if convincing to the people at large, could be an effective as well as a democratic force for peace. We have to make it clear to the common people of the world that any aggression anywhere is, in the last analysis, war against them. We have to tell them not to be misled by the familiar but insidious whisper: “Things were better when we had a war.” This is just like a criminal drug peddler saying to his victim: “See how much better it was for you when you had the drug than when you sobered up afterwards. Buy another dose.” The real problem is how to straighten out our thinking and to change our economy, to transfer control of all production to society as a whole. Only then can we have real democracy and lasting peace.

It must be understood quite clearly that the war between nations, World War III, is not inevitable and can be stopped by pressure of public opinion. The inner conflict, the class war, on the other hand, must be settled within each country without foreign-armed intervention. The peace movement cannot deny to any people the right to revolution (including counter-revolution), nor even the right to wage civil war. It can only demand that no nation’s armed forces should go into action upon foreign territory. This is aggression even when done under the cover of “defense”, restoration of law and order, or a forced vote in the United Nations. The purpose of the United Nations was to settle all international differences without war, not to provide a joint flag for the ancient imperialists “police actions”. If unchecked, such an adventure is a clear invitation to the aggressor to initiate the next world war, as can be seen by the history of appeasement during the 1930’s.

But there is one important difference between the period and the present. There were then large Powers such as the British Empire and the United States which could assume a position of formal neutrality while fascism was being built up as a military and political counterpoise to Communism. Even this formal neutrality is impossible today, only mass action by the common people of the world remains as the bulwark of peace.

11. Atomic Energy for India

The word energy is associated in the minds of most of you with steam engines, electric supply, diesel or petrol motors, water-turbines, and perhaps watermills. The word evokes others like horsepower, kilowatts, calories; perhaps also electricity and petrol bills, price per ton of coal, and increased taxes for the Five-year Plans. I want only to point out to you that these technical, social and economic considerations go very deep, down to the foundations of human society. With the coming of atomic energy, they have reached a stage, which is critical for the whole of mankind, far above mere personal considerations.

We rarely think of the simplest and most familiar type of energy, namely that derived from food-though far too many in this world still have to think of food as the one overwhelming need for their lives. Man needs from 2000 to 4000 calories of

nutritional energy per day, according to the climate, conditions of work, and type of food taken. In our ordinary discussions of a balanced diet, vitamins etc. this elementary fact is often forgotten; namely that the value of food depends upon the amount of energy it can release in the human or animal body. To make this energy available in the digestive system, man needs to have his food cooked by fire, which means another form of energy obtained by burning fuel. The history of mankind begins with the first steps above the animal stage, when man learned to control fire, and began to produce food instead of just gathering it.

The next step, the formation of human society proper, with: division of labour and differentiation of social functions, was made possible only by more power: that of animals such as cattle or horses for agriculture and transport. Human labour power was also used in greater quantity, whether slave labour, or that of paid drudges. Other sources such as windmills and wheels helped. The industrial revolution could not have been realized before the discovery and the extensive use of the steam engine, in the early 19th century. Man succeeded in the conversion of fire-energy into mechanical work. Electricity came later in that century. It could be generated with or without the steam engine, as for example waterpower or the windmill; its chief advantage lay in the transmission of energy to places distant from the point of generation. The steam engine used directly meant chains, driving: rods, gears, cables or some such mechanical transmission. You know how much human society has been changed by electricity in a single lifetime, say the lifetime of Edison.

What is the ultimate source of all such power? Food grains, fruit, nuts etc. store their energy from sunlight, which is absorbed by the living plant, along with carbon dioxide from the atmosphere, water vapour and other substances. Cellulose thus made is also the main source of the energy stored in firewood. Coal and oil are simply organic matter converted by deep burial in the earth for millions of years. Hence, all these forms of energy come from the sun, the difference being in the method by which the energy is stored. The chemical processes involved may be described as *molecular* change. The breakdown of the energy in food and fuel is also chemical and molecular. The molecules may change, their atoms do not. For wind-power, the sun heats up some of the air, which rises, and is replaced by other, cooler air. These air-currents drive the windmill. Waterpower is similarly drawn from the sun without chemical change. The water evaporated by the sun's heat rises, forms clouds, comes down again as rain. What we utilize is the how of rainwater from a higher to a lower level.

The electric energy which appears on our monthly bills (in the few Indian houses fortunate enough to have the supply) is measured in kilowatt-hours. One kilowatt-hour is equivalent to one horsepower for about an hour and twenty minutes. It is also equivalent to a little more than 860,000 calories of heat. But these are the equivalents when nothing is lost in the change from one form to the other. In practice, something is always lost. No transformation of energy is a hundred percent efficient, and most of them are decidedly inefficient. The machine loses a good deal of energy in friction; electricity is lost in transmission, and by leakage; heat is radiated away. These losses are physically inevitable, and a fundamental property of matter. But energy is also a fundamental property of matter, apart from the chemical changes and mechanical processes. Matter cannot be destroyed by ordinary mechanical or chemical processes. But if it could be annihilated in some way, an equivalent amount of energy must appear. This was finally proved by Einstein, who summed it up in the formula E=mc' which gives the absolute energy available from a given amount of matter.

Atomic energy is fundamentally different from molecular energy. For the first time in history, man has been able to duplicate the solar processes for himself on earth. Solar energy depends upon the break-down of the atomic nucleus, with the resultant emission of heat, x-ray radiation, longer electric waves, and particles such as electrons, neutrons, and the like. These

last correspond to the smoke and ashes of ordinary fuel, but are much more dangerous to man. The electricity cannot be utilized directly. The main useful output of atomic nuclear reactions is still the heat, which has then to be converted into power like any other source of heat. This might seem wasteful, but is much less wasteful than other forms of conversion. The animals, including man, cannot convert more than a limited amount of food per individual into energy, and that too not without considerable waste. Not only is the animal power-plant quite inefficient, but it has to, be stoked and fed all the time, whether any energy is utilized or not. You all know the low efficiency of coal and oil fuel. Hydro-electricity is better, but limited by lack of flexibility, and restriction to certain favourable localities.

What can humanity do with atomic energy? We must distinguish between what is now technically possible and what might theoretically be achieved in the very distant future. The most that has actually been done is to break down uranium nuclei, and to use the energy liberated. Other atomic nudie can be broken down but generally the process eats up more energy than it liberates. You know that this process has been misused. The atomic age arrived with bang at Hiroshima and Nagasaki, in the form of a most deadly bomb. Its main use since then has been as a military and political weapon in the cold war, with which certain powers have tried to cow their opponents. The sun gets most of its energy from fusion. Four nuclei of hydrogen are squeezed together under immense heat and pressure to form one of Helium. A certain amount of mass left over in the process is converted directly into energy, by Einstein's Law. This has been done on earth in the hydrogen bomb. No materials known on earth can withstand the temperatures of fusion energy. If the available uranium was properly shared, we could convert many deserts into veritable gardens, industrialize the densest Amazon Jungles, and free mankind from the worst forms of drudgery. This is no longer a technical problem, but a social one. A few pounds (about 8) of uranium sufficed to run a great submarine for seventy days. Automatic power plants could in theory be built which could be refuelled by air once every few months. Half a dozen trained men could run them. These plants could be located in any part of the world, without railways, waterways, or even road communication. But is the world prepared for this? The main question that most of you will ask is: What is the investment value of atomic energy? If the preliminary research and refining is to be done, there is virtually no investment value, for the private sector. The whole affair is fantastically costly. Those who say that atomic energy can compete with thermal or hydro-power, carefully omit to mention the fact that the preliminary costs have always been written off to someone else's account, usually that of some government. Only in some socialist countries, where uranium is relatively plentiful, and new lands have to be opened up, is it possible to utilize atomic energy properly. Even there, military considerations play a considerable part, because of the cold war.

It is true that the known resources of radioactive material in the world exceed those known for coal. But the cost of uranium is artificially high. Then there is also the question of by-products. Animal by-products are good fertilizer; the skins and meat can also be used. For human beings, the by-products are taken care of by a good sewage system, and the dead bodies; by funerals. In industrial countries, the average temperature over cities (e.g. London) goes up by a couple of degrees Fahrenheit, due to the use of coal. There is also the smoke, acid deposits that corrode buildings, carbon monoxide poisoning of the air by petrol fumes, and smog. These are trifling in comparison with the waste products of atomic power plants. The pile has to be very heavily shielded to screen harmful radiation. No one knows where to put the radioactive wastes from uranium piles. Every possible pit or mine is being rapidly filled up in the USA; the sea is unsafe, the rivers even more so. This is best brought out by the effects of atom-bomb tests. The fallout is found all over the world. The Bikini tests made grass in California radioactive, and poisoned fish that would otherwise have fed Japanese a few thousand miles away. Excessive doses of

radioactivity always cause serious changes in all living organisms. Some of these changes lie in the mechanism that enables the organism to breed. Most of these hereditary changes are lethal; that is, they kill the organisms born in the next generation. The Japanese have followed up persons exposed to atomic radiation at Hiroshima. Many of the children born to women who have been so exposed can hardly be called human; but they do not live to grow up. The real danger lies in the minute genetic change that does not show itself for some generations. It is known from experiments on smaller animals that these changes, when fully developed, may lead to incurable mental derangement within a few generations. By the time we know what the effect on mankind is going to be, it will be far too late to do anything about it. The changes will have been bred into millions of human beings of that generation and, remain thereafter. This is not a disease, or an infection that I am talking about, but hereditary insanity, physical degeneracy, and worse. The only cure is to, stop all atomic tests immediately, and to take great care that the waste products of atomic power stations for peaceful purposes will be safely isolated. The advanced countries have quietly reduced their atomic power programs. The prestige of having atomic power stations does not compensate the extra expenditure or the extra danger involved.

Where does that leave us in India? We do need every available source of power quickly. Can we utilize atomic power for national progress? This question has already been answered in the affirmative by the high command. The papers inform us that another hundred crores or more are to be devoted to this purpose beyond undisclosed millions already spent. It was announced in August 1956 that India had joined the ranks of the atomic-energy producing countries. Actually, we were not then producing any atomic power. Though a second reactor costing another ten crores of rupees has gone into operation, and the staff has reached over two thousand highly trained graduates, we still produce no utilizable atomic power. The setting up of atomic power stations in other countries is now quite easy. Even China has one giving 7000 kilowatts since last year, and may build more. The USA, UK, USSR, France, Canada and some other countries could build one or more for us-if we are willing to pay the cost. The question is whether this cost is worthwhile.

I do not propose to answer this question, because all of you here are intelligent to work out the answer for yourselves. But I do wish to point out that the main work in producing atomic energy has already been done without cost to India by a permanent source, which has only to be utilized properly. This generous source is the sun, which goes on pouring its blasting rays into every tropical country, at an uncomfortable rate. Can solar energy be used directly?

The answer is yes. The USA, Russia or England, for example, do not receive so much direct solar radiation as India. There is no reason why we should ape them in all things, including the development of atomic energy at a fantastic cost with low-grade Indian uranium. On an average day, every hundred square meters (1100 square feet) of area will receive about 600 kilowatt hours of heat. This comes to over 160 pounds of high-grade coal, or more than 16 gallons of petrol, in energy equivalent. If it could all be utilized at 100% efficiency, we could evaporate some 240 gallons of water per day. At present, the best-known efficiency of utilization is by solar batteries, which are between 11% and 15% efficient. The Americans are already using such batteries to boost telephone currents in long-distance lines. If I could use such batteries on my own bungalow roof, it means 7 kilowatts for every hour of average sunshine, say 60-kilowatt hours per day. This would give my family enough power for ail cooking, lights, hot water gadgets, (vacuum cleaner, frigidaire,) air-conditioning and still leave enough for an electric automobile run on storage batteries. The Russians produce enough steam power from solar energy to supply all needs of a modern town of over 15,000 inhabitants in the southern USSR. Even as early as 1876, a 2.5 horsepower steam pump was run on solar heat in Bombay. A striking instance of the immense reach of solar power comes from the space-satellites, which send their

information to earth by radio transmitters that run on solar batteries. The best of them continued to communicate with our globe from well over 20 million miles away.

It seems to me that research on the utilization of solar radiation, where the fuel costs nothing at all, would be of immense benefit to India, whether or not atomic energy is used. But by research is not meant the writing of a few papers, sending favored delegates to international conferences and pocketing of considerable research grants by those who can persuade complaisant politicians to sanction crores of the taxpayers' money. Our research has to be translated into use. The catch in solar energy is its storage. The current you may want at night can be produced irregularly in the daytime. This is not an insoluble difficulty. Quite efficient forms of storage batteries are known. It is possible to combine several uses with mechanical storage. For example, water could be pumped up into 50-foot village towers during sunlight hours, and then allowed to run out for irrigation, or home use, through low-pressure turbines that generate electricity whenever wanted. This is not very efficient at the second stage, but the main purpose of augmenting our poor water supply will have been efficiently served, village-by-village.

The most important advantage of solar energy would be decentralization. To electrify India with a complete national grid would be difficult, considering our peculiar distribution of hydropower and thermal resources. With solar energy, you can supply power locally, with or without a grid. Solar power would be the best available source of energy for dispersed small industry and local use in India. If you really mean to have socialism in any form, without the stifling effects of bureaucracy and heavy initial investment, there is no other source so efficient. Take the simple problem of reforestation, which alone can change India's agriculture, preserve her rapidly eroding soil, and increase production. This problem is insoluble unless people have cheap fuel for cooking, so that they need not cut down trees. The solar cooker if it worked, would have been the answer. We know that the cooker produced, some years ago with such fanfares and self-congratulations is useless. Even a schoolboy should have known that the pot at the focus of the solar cooker, being nickelled and polished, would reflect away most of the heat. But our foremost physicists and research workers, who rushed to claim personal credit and publicity, did not realize this. That is the result of paper research and research for advertisement. If we get over this fundamental hurdle, we have the real cost-free source of atomic power, the sun, at our disposal, for more than eight months of the year.

Solar energy is not something that any villager can convert for use with his own unaided efforts, at a negligible personal expenditure, charkha style. It means good science and first-rate technology whose results must be made available to the individual user. The solar water heater is the simplest to manufacture: a black absorbing grid like an automobile radiator, and an insulated storage-tank. No moving parts are involved. The water can be delivered much hotter than needed for a bath, but below the boiling point. Such heaters are already used successfully in Israel and elsewhere, and would save a great deal of fuel by themselves in the Indian household. For the steam engine, it is necessary to concentrate the sun's rays, usually by a light silvered concave reflector, which moves with the sun. These are also quite practicable, and in use. Direct conversion of sunlight into electricity is familiar to many of us as the photoelectric cell, and the photometer used for correct exposure. These are very simple and efficient to use, but cost more money to make. The technique has now been simplified and the cost reduced by careful study of semiconductors. The most effective solar battery of which I have any knowledge is based upon silicon-zinc crystals. Their production, too, is commercially successful, but needs still more research-which continues uninterrupted in other countries. The Chinese use semi-conductors directly to produce enough electricity even from the waste heat of an ordinary kerosene lamp to run a radio set; their appliances are on the international market now. What India could use best in this way still remains to be determined. The principle involved in the use of atomic energy produced by the sun as against that from

atomic piles is parallel to that between small and large dams for irrigation. The large dam is very impressive to look at, but its construction and use mean heavy expenditure in one locality, and bureaucratic administration. The small bunding operation can be done with local labour, stops erosion of the soil, and can be fitted into any corner of the country where there is some rainfall. It solves two fundamental problems: how to keep the rain-water from flowing off rapidly into the sea, unused; and how to encourage local initiative while giving direct economic gain to the small producer. The great dams certainly have their uses, but no planners should neglect proper emphasis upon effective construction of the dispersed small dams. What is involved is not merely agriculture and manufacture, but a direct road to socialism.

Every notable advance in man's control over new sources of energy has been hampered by outworn superstition or obsolete social forms. Fire is regarded today as a convenient tool at the service of humanity. Primitive man thought it necessary to worship fire as a god. *Agni* received human and animal sacrifice; vestal virgins might be dedicated to his service. Is it less miserable a superstition that calls for the sacrifice of millions of men and animals, living or as yet unborn, to atomic tests and radioactive fallout? It seemed inevitable to Victorian England that dreadful industrial slums should accompany the first large-scale use of the steam engine; it also seemed necessary to conquer many colonies for supply of raw materials and as market for the finished goods of the factories that the steam engine first made possible. We claim to know better now. If so, has the time not come to change society so that the new discoveries will serve the needs of all mankind rather than the perverted greed of the few? Then, and only then, will it be possible to determine how much effort should be spent relatively on the development of the various sources of energy.

12. SUN OR ATOM?

Mankind, so we are told, stands upon the threshold of a glorious new age, the age of atomic power. This new form of energy should bring about a fresh industrial revolution, just as the harnessing of steam generated the first industrial revolution, which was reinforced by electricity and oil. Man need perform no drudge labour, and need never lack for anything, once this magnificent source of power is fully developed.

There are a few pitfalls on the way to this newly glimpsed paradise. Steam did indeed change society, but the grime and the misery of industrial slums, the mental tension of life in the big cities, take mankind a step further away from utopia. Atomic energy threatens far worse evils as it is being developed today-namely, for private profit and lot war. The by-products will be much more dangerous than ordinary coal smoke and oil-exhaust gases. Indiscriminate atomic bomb explosions, whether for testing or actual warfare, will leave a deadly ineradicable mark on the heredity of all living matter, including man himself. Already, before we have had any decisive benefit from atomic power, the problem of the radioactive waste material, which appears in the processing, has become formidable. This leads some prophets of gloom to the other extreme: humanity destroys itself by striving for progress; science is an evil. Let us go back to nature, the simple life of the villager.

This reaction is puerile. The clock cannot be turned back. Science is not to blame, only the greed that misuses it. Man in the state of nature was helpless in relation to the environment. For that matter, edible grain like rice and wheat is as artificial as a brick house; it took our ancestors a few thousand years to develop them out of the grasses; and if human cultivation stopped, nature would not give such food crops. The whole question of energy, atomic or any other has to be considered dispassionately,

without sentiment.

Power is energy under control, in form suitable for use. The question, therefore, is: what are our sources of energy, and how may their output be suitably harnessed.

The most familiar form of energy is food, which every human being needs even when he does nothing else except breathe, just to maintain his body temperature at 37 degree Centigrade. In meat, the energy has been stored up by the animal ultimately from vegetable matter. The plants make their substance principally from carbon dioxide and moisture, (with a little nitrogen and other elements) which are combined by the living plant under the absorption of the sun's heat and light. In other words, plants (and therefore animals) store up the energy emitted by the sun and received by the earth as radiated heat and light. This also accounts for the energy we get from firewood, coal and oil. Coal and oil come from living matter (mostly extinct vegetation) compressed in the crust of this earth millions of years ago. Fire, combustion in general, is the oxidation of matter - a molecular process that usually gives out energy. Then, we have waterpower, which utilizes the downward movement of water under gravity. But bow did the water get up in the first place? The sun evaporates the surface water, mostly from the sea and the moisture, which combines in the form of clouds, is precipitated again as rain. Once again, the energy derives from the sun. The wind, whose mechanical energy becomes so terrifying in the Storm and is not easy to harness on a large scale, is caused mainly by unequal heating of the atmosphere. The tides, whose energy could also be used by good engineering on a far larger scale than hitherto, are caused by the rotation of the earth and by the gravitational pull of the moon to which of the sun adds comparatively little.

It is seen that virtually all the energy man uses comes from the sun. How does the sun generate this terrific amount of energy, of which a very trifling portion, received by us at the distance of 96 million miles, has kept all humanity going? The processes that generate energy within the sun are not simple, and have often to be understood by the aid or the most complicated theory. There is one essential difference between the way the sun's energy is generated and the modes of generation of energy we have surveyed on the Earth. Our energy was obtained through molecular changes, which means that the atoms within the molecules (say of cellulose) are at most recombined into other molecules but do not lose their nature otherwise. The sun breaks up the very nucleus of the atoms and crushes the pieces to form other elements. In particular, four atoms of hydrogen can be crushed together to form one of helium. A small amount of matter is then left over, and its destruction gives almost all the energy that we feel on earth as coming from the sun.

The great achievement of our scientists has been that, for the first time in min's history, it has been possible to match the sun's activity, to duplicate in principle the processes by which the sun creates this energy. It is significant that the energy was developed for war, and its first use was to wipe out Hiroshima, though all the fundamental research necessary had been completed in peacetime. However, this first step towards matching the sun does not go far enough. The energy is not obtained by fusion of atoms as in the sun, but by the break-up, the fission, of uranium into lighter elements. The problem of fusion energy still remains to be solved.

It is not necessary here to recapitulate the wonders of atomic energy—if it could be properly utilized for peaceful purposes. The first atomic power stations are already in operation, but none where they are most needed. The atomic power station can be set up in remote places, needs very little replacement of fuel. The personnel and maintenance staff is also remarkably low. So, it should be ideal for underdeveloped and technically backward countries, say in Asia and Africa. The catch is the profit-motive, and the initial cost. The known resources of fissionable material are estimated (in terms of energy) at about twenty times the known coal resources. But coal is much easier to mine, and needs no delicate refining as does Uranium ore. Research is already under way, primarily in the USSR, which will bring the cost of atomic power below that of power from coal, but the realization needs time—and peace! Hydro-electricity needs no fuel but is tied to certain localities suitable for power plants. It's waste product, water, can be used in India for irrigation in multipurpose schemes. The high cost is of the first installation. Atomic stations could be portable, and be used for quite efficient marine engines. They have already been used for American submarines.

In all this, the question of India has naturally to be foremost in our minds. Our hydroelectric schemes have to be concentrated in certain favourable localities, away from the densest centers of population. Our coal is in Bihar, not of the highest industrial quality and none too easy to transport into the heart of our country. Our fissionable materials consist of the lowest grade uranium in Central India, plus the radioactive (Thorium) Sands of Kerala, which are not immediately utilizable for power production. Add thereto the low achievements of our costly but inefficient science and technology, and the problem becomes formidable. All the more so because foreign sources of uranium are controlled, atomic research is everywhere a painfully guarded secret; power politics has entered into the thing else, with new gusto. Is there no other way that would be more paying, without interference with any other mode of power-production?

The answer, for India is a definite YES. Instead of competing with the sun, what we have to do is to find some way of utilizing what the sun thrusts upon us with matchless persistence. Let the sun split the atom, fuse the nuclei for us. Why should we not use the energy directly rather than wait for it to be absorbed by plants, converted into firewood, and so on? In what follows, I leave out the detailed calculations (which exist) of so many ergs per centimeter, and speak in general terms that any layman can understand.

The sun's energy can be used directly. Indian villagers know that in summer, a dark copper vessel filled with water and left all day in the summer sun will give water that is uncomfortably hot to touch. Indeed, we have heard a great deal in recent years about a solar-cooker, which reflects the sun's heat on to a small vessel. The principle is sound enough, as any boy knows who has set paper on fire by concentrating the sun's rays through a burning glass. The much-publicized cooker is a failure primarily because the pot is made of shining white metal, which reflects the heat; and the mirror is too small, as well as badly designed. But steam engines have been run quite successfully in other countries from the sun's heat, concentrated by a large concave reflecting surface upon a boiler at the focus of the mirror. The mirror has to be tilted constantly to "catch" the sun, which is done by a clockwork mechanism. The mirror of an ordinary anti-aircraft searchlight concentrates the sun's rays sufficiently to give a small furnace in which the most refractory metals can be melted, and ordinary metals vaporized, in a flash.

There exist more direct methods for conversion of solar energy into power. One such is familiar to many as the photoelectric cell, used for measuring light. This works because alkali metals (like sodium) shoot not electrons, and so generates an electric current. These alkali metals are rather costly to produce in pure form, and oxidize rapidly without special precautions. Other and much cheaper methods of generating electricity directly seem within reach of success. In fact, a small solar battery for boosting transcontinental telephone transmission is already in use over desert areas in the USA. The most promising technique today is that of silicon crystals on the surface of which very thin deposits of some metal like zinc have been made. The problem of producing these cheaply has yet to be solved, but again, so far as known, the Soviet products are most efficient in this line.

The cost of research on direct utilization of solar energy would be far lower than for atomic energy. India has much greater supply of solar energy than most other countries; in fact, the problem is to keep the land from being blasted altogether by the sun. One difficulty is that the sun's energy is not constant. There is the variation between sunrise and sunset, with nothing at all at night. Again, cloudy days make a difference. The problem of storage, however, is not too difficult. Better storage batteries can certainly be produced, to give long life without heavy servicing. Another method would be to pump water by use of solar energy, at whatever variable speed the into high level tanks (say on towers). The water can then come down by gravity through turbines, which turn electric generators, and can be further used for irrigation. The advantages are that the fuel – the sun's radiation – costs absolutely nothing, and there are no harmful exhaust gases or radioactive byproducts. Moreover, the installation can be set up anywhere in India, and will work quite well except perhaps in the heaviest monsoon season. The research is of no use for war purposes. This is why it attracts some of us, but does not attract those who control the funds.

There are other sources of energy, too, say from the heat beneath the earth's crust. But this would be costly and difficult as a feat of engineering to tap, and to convert into power utilizable on the earth's surface. The cosmic rays of which we hear so much have too little (total) energy to be of much use today. The tides have scarcely been harnessed, particularly in places like the Bay of Fundy, where they are fantastically high. But the huge primary source of energy today remains the sun. Direct utilization is hindered only by the desire for prestige, which makes India waste so much of her money in supposed research along other lines.

13. SOLAR ENEBGY FOR UWDERDEVBLOPED AREAS

A Textbook very popular in the U.S.A. before World War II and perhaps still used widely in American high schools for the teaching of physics, says:

'The earth is continually receiving energy from the sun at the rate of 232,000,000,000,000 horsepower, or about a seventh of a million horsepower per inhabitant. We can form some conception of the enormous amount of energy that the sun radiates in the form of heat by reflecting that the amount received by the earth is not more than 1/2,000,000,000 of the total given out. Of the amount received by the earth, not more than 1/1000 part is stored up in animal and vegetable life and lifted water. This is practically all the energy which is available on the earth for man's use.'

This statement is taken from pp. 214-215 of Millikan, Gale and Coyle's 'New Elementary Physics.' (Bolton, 1936). Prof. Robert A. Millikan, the senior author, was among the outstanding classical physicists of his day and awarded a Nobel Prize for his profoundly illuminating experiments. In spite of the growth of the earth's population, the discovery of atomic energy in utilizable forms, and some variation in solar radiation, the facts given are true even today. The energy discharged by the sun upon earth still comes to something like 140,000 horsepower per each inhabitant, and surely much less than a thousandth part of that is utilized by man, though nearly a thousandth part may be stored up in some way by nature.

This storage is in the form of solar energy utilized in converting carbon dioxide from the air plus water vapor into vegetable matter. 'Lifted water' refers to water evaporated by the sun, which comes down upon a higher level in the form of rain, and may be utilized as hydropower. Animal life reuses the vegetable matter taken in as food, and some animals go a, step further in eating others. Man derives his own physical energy in this way, and utilizes more solar energy in the process of cooking his food - though the energy of the fire is not thereby stored up.

Here, one has to make a sharp distinction between such commonly used terms as mental energy, spiritual energy, soul force, etc., and the precisely measurable 'energy' of the physicist, with which alone this note is concerned. Man needs this not

only for special muscular labour but even in breathing, in keeping his body temperature at 370C and in all other bodily functions, without which he ceases to exist as a human being. This fact is clearly recognised in the measurement of nutrition by caloric content: '3,000 calories per day are needed for average labour in such and such a climate', etc. These calories have already been measured by prolonged physical experiments upon human beings fed various sorts of material. The rate of utilization of the caloric content depends upon individual digestion, palatability, vitamins, balance of diet etc. but in the end, the maximum amount of energy to be derived from any given diet is a clearly measured physical quantity.

Horsepower

Men, and animals that are used to ease man's labour (oxen, horses, llamas) are rather inefficient in converting their food intake into mechanical work. Otherwise, slavery would have lasted much longer and we should not have to worry about replacing the bullock cart and *tonga* with something more suitable. Industrialization is not merely a fashion but a necessity, based in the final analysis upon the need for more utilizable energy. The horse and ox have to be fed whether they work or not, which decreases their net efficiency still further, apart from rest-periods, the non-working extremely young, very old, or - non-working female animals (without which the species cannot be maintained). A horsepower as unit of work was measured as the work done by specially trained, powerful draft horses, accurately measured to fix the unit; but the average work done by the average equine animal throughout his whole life-time is a small fraction of the rated horsepower.

It ought to be noted that when we talk of energy from coal, oil, etc., we still mean solar energy stored up in the past by living matter. Hydroelectric energy comes, as noted above, from water raised by the sun. Millikan did not mention sails and windmills, which make very little difference to the total energy now utilised; but this is again solar energy, for the movement of air-masses is due to unequal heating by the sun which causes some air to rise and other to move into its place. The one possible exception to the statement that normally utilized energy is ultimately solar may be from tidal power stations, possible in a few parts of the world (like the Bay of Fundy) with very powerful tides. This energy comes mostly from the drag of the moon upon the waters of ocean.

The Main Question

The main question then becomes: what new methods are there for the utilization of all this wasted solar energy, which costs nothing to puce at the source?

The sun does not discharge its energy in concentrated form, or life would have been impossible on this earth of ours. Nor is the energy equally available at all times. Nights and very cloudy days mean virtually no solar energy ready for the tapping, while the rate varies in summer and winter, tropical lands and the Arctic's. The main problem then falls into three parts: concentration and storage - all of which is done, inefficiently or not, by plant and animal organisms. The main reason for wrestling with the direct problem is that all known sources of such ready-stored energy will be exhausted in the calculable future, whereas the cooling of the sun lies millions of years away.

Concentration is done by familiar means, e.g., the burning glass which most of us know how to use. The most spectacular of such concentration is for solar furnaces. The reflectors of discarded army searchlights can concentrate enough energy from the sun to melt any known metal, and even to vaporize such refractory metals as tungsten. The flashing-up of a tungsten 'candle', once seen is never forgotten. But of course, this is a specialized use. Far more useful would be solar water-heaters, which can

easily and cheaply be made with no moving parts. The water is heated directly in a pipe-grid, rises (because warm water is lighter than cold) into insulated containers, and remains close to its maximum temperature for 48 hours. Such heaters are in actual use in Israel and other places for household purposes.

Boiling the water could give solar stills, most useful in parts of Rajasthan and Kathiawad where the water is brackish, useless for drinking and even for industrial purposes. They are used in other countries, but apparently not in favor with us. The easiest step is a solar cooker. With aluminum reflectors, these can be used by any household to boil some 40 liters of water an hour; or to do the corresponding amount of other types of cooking. I have seen them in very successful operation elsewhere. Finally, such boilers could and have actually run steam engines. One was used in Egypt early in this century; another ran a pump in Bombay in the 1880s.

Such apparatus needs some attention because the sun keeps moving in the sky. The cooker can be turned a little every half hour by the housewife by hand. The same turning can be done continuously by automatic clockwork, nothing more complicated than the filling of sand, which runs out, to allow the counter weight to rise, thus turning the cooker. Finally, fixed-position boilers exist for continuous water heating on a large scale.

The Catch

The catch in all this is the variation in solar energy. One cannot run the solar steam engine at night. However, cooking during daylight and storage of hot water are certainly possible. The pump can be run all day for irrigation, except perhaps in the cloudy monsoon, when irrigation would be unnecessary in any case. It has even been suggested that the day-light pumps could raise water to the top of 50-foot towers, and that electricity would then be generated by properly designed turbines which ran on the water released for irrigation at night. This is a solution of the problem of storage.

Direct conversion is also possible. Most camera-users know the photoelectric meter which measures the light by measuring the electric current generated when the light falls upon alkali metal, sodium or potassium. Other such electric cells are possible and can be manufactured at lesser cost. Storage here would mean storage batteries of some sort. Booster cells which work by sunlight are already in use for telephone lines which run across the USA through desert area where the addition of extra current would increase costs beyond measure. The cells are put on top of the telephone poles and help out precisely when the load is at maximum.

Costs

As things stand, solar energy is costly, simply because it runs on a laboratory basis. The lands where technology is most advanced are just those, which have very little sunlight as compared to India and Africa and where conventional forms of energy are highly developed. But mass-production is quite feasible and would reduce the costs enormously. The best such example in other fields is of aluminum, which is the commonest metal in the earth's clay. Pottery, the first artificial substance made by man, is possible only because of the properties of aluminum hydroxide. But extracting this metal was a most costly process and aluminum was, a century ago, costlier than gold. Technology has made the metal cheap - as no amount of technology could make gold or platinum cheap-and we use aluminum without further discussion as to its advisability.

There is a second economic factor involved besides cost. Solar energy has no evil by-products; no ash, carbon monoxide or other poisonous gas, noxious cancer-producing atomic waste or the like. Furthermore, there is a whole economic cycle involved. Say a successful solar cooker is available in India, nothing more. Then it would be possible to reforest the land now

denuded of all trees, which no *vana-mahotsav* can make green again as long air the peasants are short of fuel.

Reforestation means a better climate, springs that flow for a longer period after the monsoon, clear water in the rivers, more timber for construction work, better agriculture. The sole proviso is that fuel should be available apart from growing vegetation. If we try to get this from kerosene oil, say, the very minimum needed for cooking, without much light and without hot water for the bath is easily calculated. It comes to not less than 500,000 barrels of refined kerosene daily. Whether we can produce that much oil and distribute so much refined product over the whole country is a question anyone can ask - and answer.

The natural question at this stage is: what is holding things up? Why has nothing been done? The easiest answer to give is. That all this is in some way impractical or it would have been done long ago by the advanced countries - which have not the solar energy, of course! But rather than go into an abstract discussion of what cooperation would be needed between private and public sectors, science, engineering, technology of mass-production, and so on, let us consider one case in point which may answer this final question.

Short-Lived Experiment

Some years ago, an Indian solar cooker did appear on the market. It was shown in the newsreels in our cinema theaters. The President, the Prime Minister and others saw the demonstration and tasted a meal, which was announced as having been cooked from scratch on the said cooker in just 30 minutes. The statement in itself was not improbable, but there is no cooker on the market now. Some specimens were sold quickly and the manufacturing company is reputed to have made its profits by selling off the stainless steel and the machinery, whether as scrap or as useful materials. The cooker, when tried by ordinary mortals away from newsreel cameras, just refused to work.

Any scientist could have said why. The reflector, which concentrated the solar energy, was too small in area. In addition, the pot at the focus was just as bright, of polished stainless steel, as the reflector, thus turning away most of the heat concentrated upon it. Any high school student could have said that the cooking pot must be black on the outside, and then calculated the necessary area for the mirror. Where were our world-famous scientists? The sole announcement that I have read was that the scientists of the National Physical Laboratory had designed the said cooker, inspired by a great thought that the then President had during his *satyagraha* days. With this bit of gratuitous publicity, the scientists returned to their profound speculations. Some of them managed to represent India at international conferences on solar energy, nevertheless. The Planning Commission was too busy with philosophical and scholastic essays to bother about the question.

In The Future

These strictures seem rather harsh, but surely not undeserved. When some years ago, the main ideas of this note were spoken out in a popular lecture, the matter roused some heat not due to the sun. The sole outcome was to question the facts-which appear in an elementary textbook written by a scientist of repute. Questions were asked in parliament and answered by high authority with the words that such projects are designed to keep India backward, in the bullock-cart age. This, in spite of the remark made during the lecture that the bullock-cart is inefficient, and that India needs every form of energy it can afford. A question of science, technology and economics was reduced to one of ostentation and prestige. However, the sun has not yet been abolished by decree, so that the matter may be taken up at some future date when common sense gets a chance.

14. EINSTEIN: THE PASSIONATE ADVENTURER

" That's our professor Einstein", said the American taxi driver with tenderness and pride rare in his notoriously disrespectful élan. The recipient of this accolade was clumping vigorously along the Princeton sidewalk one gloomy December afternoon in 1948. The famous mane of hair, now white and, thinner, was still unprotected by a hat. Shirt and necktie had been replaced by a sailor's knit jersey, socks dispensed with altogether.

This was an unforgettable first glimpse of the man whose theories had evoked the complete spectrum of comment from derision to adulation. The simplicity of his dress was matched by his bearing at all times, even in scientific discussion. His life, however, had not been as tranquil as his aspect. This pioneer citizen of a new universe bad had to change his earthly citizenship several times. Germany, the country of his birth and education, denied him full effectiveness because he was a Jew. Zionism, which he tried so hard to serve, did not gain because he took the advice of people without vision. His personal judgment of scientific merit came to be regarded as worthless, for anyone could - prey upon his abundant kindness to obtain a superlative testimonial.

Popularly labeled the world's greatest mathematician, he could never be compared to the really great mathematicians of his day such as Dedekind, Poincare, Hilbert. The imputation that he was the father of the atom bomb led him to say bitterly towards the end of his life that if it were to do over again, he would prefer to be a plumber or a tramp rather than a scientist. He did write the letter that led president Roosevelt to allocate funds for the immediate development of nuclear chain reactions. Not he but other Princeton colleagues brought their talents to bear upon the technical development of the A-bomb, heedless of disaster to humanity. It is stated that his equation E = m x c x c led inevitably to the horrors of atomic warfare. This is true to about the same extent that the Sermon on the Mount led inevitably to the sack of Constantinople in the Fourth Crusade.

Einstein's great achievement was a completely new way of looking at the material universe. The amount of matter in space - at any time affects the properties of space itself, and also the measurement of time. Other radically new scientific ideas that characterize the first half of our century crystallized rapidly about the theory of relativity.

The fine mechanical system developed by Newton and his successors had begun to show small but clear and unmistakable flaws by the end of the 19th century. The planet Mercury did not move with the proper clockwork accuracy. Both electricity and magnetism obeyed Newton's inverse square law, just like gravitation; but what was the connection between them and gravity? Ultimate particles of matter carried electromagnetic charges. Why did they send out electromagnetic waves-light, as gravitation did not? Why was the velocity of that light completely unaffected by the earth's rapid movement through space? If mass and energy were indestructible, how did the Curies' new element Radium constantly shoot off particles as well as the x-rays discovered by Roentgen? Man's search for new sources of power and energy was being blocked by outworn notions of matter.

Einstein helped solve more than one of these problems, but his main work developed out of the question: why does light travel with a speed independent of its source? He turned the question about, and said that the constant velocity of light is a fundamental property of space. Two observers at a distance could compare their watches and yardsticks only by flashing light signals whose velocity remained the same for both, no matter how they moved. This leads to entirely new concepts of measurement and simultaneity. It also relates mass and energy, which become two interchangeable aspects of the same thing.

Philosophers and theologians dragged in the Bible, Karl Marx, immorality of the soul and God's knowledge of mathematics to attack Einstein with a viciousness not yet forgotten. He alone saw beyond mere verbal controversy. Some new,

powerful tool was needed for the analysis of time and space. Not only had all major known facts to be explained, but it was essential to predict phenomena not as yet observed. This tool was discovered by him in the work of two Italian mathematicians Ricci and Levi-Civita. Its use had to be mastered painfully. Then came the "passionate adventure into the unknown" upon which he looked back as filling the finest years of his life: the precise mathematical formulation of the unity of space, time, and matter. The sublime exaltation of such discovery has to be experienced. It cannot be explained to those who seek it in mescaline, or the ascent of impossible mountain peaks. He took good care to associate competent mathematicians with his work. The insight, however, was his alone. So many of us produced beautiful and intricate formulae without knowing what to do with them, while he thought his way slowly to Nature's secrets.

The first magnificent results were published during the early years of that, senseless slaughter - the First World War. The new theory explained not only Newton's gravitational law, but also the curious behaviour of Mercury. There was a spectacular prediction, that a ray of light passing close to the sun would be beat slightly. As light has no mass, Newton's theory could not explain this; even if the rays did have weight, the deflection by Newton's theory would be only half that given by Einstein. Special observations made during solar eclipses confirmed the Einstein law. The theory passed thereafter as current coin into the common treasury of man's knowledge.

It was not in astronomy but in the opposite direction that the influence of relativity was indispensable. What happened inside the atom received a better explanation. Einstein went on to combine gravitation with electro-magnetism in a succession of unified field theories, over the years 1929-1949. When it appeared that virtually no solutions existed of his final equations, he had the courage to face possible ruin of twenty years' hard work: "Perhaps, my dear colleague, Nature does not obey differential equations after; all". The solutions were found later by Hlavaty. However, Nature still has the last word. The inexhaustible properties of matter continually revealed by experiments in nuclear physics have outstripped all theories.

It seems to me that we now stand close to the threshold of a new life, as far above any pre-atomic utopia as that was above the early Stone Age. If we really cross the threshold into a new age, it will be by renouncing war and controlling greed for individual profit. Then indeed may our descendants abandon this little cinder of a planet for really brave new worlds in unbounded space. Busy with the creation of real history, they might no longer be conscious of their historical past. But one of the individuals who led us nearer to the threshold was the passionate adventurer - Einstein.

15. G.D.BIRKHOFF: A TRIBUTE

By last airmail came unexpected news that the leading American mathematician Prof. G.D.Birkhoff (not to be confused with his distinguished son and colleague Garrett Birkhoff) of Harvard had suddenly passed away. It is unfortunate that this note, which could have served as tardy appreciation on the occasion of his sixtieth birthday (March 21, 1944) should have to be turned into a rather slight obituary.

Birkhoff's principal significance in contemporary science was that with him American mathematics came of age. He first reversed the general trend of a pilgrimage to Europe for deeper mathematical studies, which was considered essential for every serious American student before him. When continental mathematicians first referred to his work, it was (as for example Wilhelm Blaschke) with the emphatic qualification "der Amerikaner Birkhoff" and that citation, I feel certain, must have been regarded as a greater triumph by Birkhoff himself than the innumerable honorary degrees, fellowships of academies and

learned societies (led by the Academie des Sciences at Paris), prizes (none of greater distinction than that of the newly opened pontifical academy) showered upon him throughout his abruptly terminated scientific life. Not that he was not an internationalist, for he did his very best to save Gottingen as a mathematical center during the depression, before Hitler destroyed all such hopes. After that he was instrumental in bringing to the USA the finest of the exiled talent, though he could never have been mistaken for a prosemite by anyone who spoke with him for more than thirty seconds on the subject. Nevertheless, he was and always remained an American, at times aggressively so, with forthright direct action and oversimplified thinking-except in his mathematics. When Indians like T. Vijayaraghavan and S. Chandrasekhar received the courtesy that he always lavished upon all whom he believed to possess any degree of scientific competence, Birkhoff would manage to persuade himself that he was doing it for the good of America and not because of his own genuinely kind and hospitable nature.

To appreciate what this means, without letting it go as a grudging compliment to the memory of great scholar, one would have to study the mathematical atmosphere of Birkhoff's younger days when the very claim to be an American scholar exposed the claimant to ridicule at home and polite contempt abroad. The true scholars of his formative period were either imported, like Sylvester and Bolza, or were isolated and frozen out for lack of appreciation. Josiah Willard Cibbs had to be resurrected by the German chemist Ostwald before the USA realised that it had actually produced a great scientist. Eliakim Hastings Moore, Birkhoff's beloved and most influential teacher, found his 'general analysis' totally neglected till the fame of his distinguished pupil directed the attention of others there-to. By that time it was much too late for the method to be effective or Moore's notation to be adopted, for Hilbert's followers had skimmed all the cream off that particular jug. This was inevitable in the undeveloped state of American mathematics, though Moore himself was the first in any country to realize the full connotation of Hilbert's work on integral equations which has had so profound an influence upon current scientific activity through modern quantum theory. Birkhoff studied under Moore at Chicago in 1902, came to Harvard (the only other American mathematical center then existing) next year with Moore's approval, worked rather unenthusiastically for two years, and returned to Chicago for another two years of real inspiration. The stage at Harvard was then fully occupied by the imposing presence of B.O. Peirce who made up for a total lack of mathematical intelligence by his preternatural solemnity and an impressive beard (which earned him the soubriquet of " Santa Claus " from Birkhoff's generation of students). Peirce's ostentation overshadowed the real mathematical ability of his son Charles, whose unconventional life and thought (like that of G. W. Hill) led to complete intellectual obscurity and a miserable academic career with the doubtful compensation of posthumous honor. Far better as a teacher was William Fogg Osgood, a much younger member of the Harvard mathematical department which he succeeded in raising to pre-eminence in latter days. Osgood had an excellent mathematical training under Felix Klein, was instrumental in bringing the modem analysis of Weierstrass with its battery of epsilons and deltas to bear upon the American student, knew what the Erlanger programme was, possessed the adjuncts considered necessary for a good teacher in his day including beard, pompous mannerisms (plus the affectionate student-bestowed title of "Foggy Bill") and lack of imagination' He failed to inspire Birkhoff, though he did succeed in bringing him as a professor to Harvard from Princeton in later days, and Birkhoff treated him with all the formal respect due to a teacher. But their mutual regard went no further. Osgood privately characterized Birkhoff's presentation as "sloppy", which it certainly was, and hence by innuendo his thinking too, which was certainly never sloppy. It is to be noted that these two leaders of scientific endeavor managed to keep their personal views about each other from interfering with their work and close cooperation in the same University department; this is a lesson that has yet to be

learned by academicians in out own country. The last of Birkhoff's teachers worth mentioning was Maxime Bocher whose crystal clear lectures derived from his crystal clear thinking. The very perfection of these lectures, however, left the budding young research worker cold with unfortunate after effects; for, Birkhoff's own lectures left very much to be desired even twenty-five years later. Those of his lectures that the advanced students did understand were invariably considered by them the most inspiring that they had ever heard, but usually he lost himself, the subject, and the audience in his own latest brainwave which might have developed that very morning between the breakfast table and the lecture room.

The rest of Birkhoff's story is precisely that of the growth of modern mathematics in the USA, of the substitution of a few isolated individual workers by the general development of indigenous talent and, a powerful school took the lead over all others soon after the First World War. The best view of this development as regards persons and performance is to be had from Birkhoff's own semi centennial address (1938) to the American Mathematical Society, "Fifty Years of American Mathematics". In this his thorough grasp of many branches of the subject shows itself, along with his breadth of vision, though he consistently minimizes his own contributions and the reader will not realize that a goodly number of those he praises with justice were made by his own brilliant students, often with his direct inspiration. He was early associated with Vandiver in work on Fermat's last theorem, and his pleasure was unbounded when he saw in the advance copy of Landau's book on number theory that a whole section had been devoted to the work of his early collaborator, gaining him long-delayed recognition. What first made Birkhoff himself internationally famous was his simple proof of Poincare's geometric theorem on the existence of invariant points for a ring transformed into itself with the two boundaries advanced in opposite direction. Poincare died without proving the theorem and a proof supposed to have been discovered by Phragmen actually came to nothing, leaving Birkhoff in sole possession of the field and the eminence that was his due. Before this, his work on existence theorems for difference equations, showing their close parallel behaviour with differential equations had given him substantial reputation. He followed this success up with further important work on dynamics, a continuation of Poincare's ideas, which approached the dynamical existence problems of stable motions, of periodic orbits, etc. by methods of topology and differential geometry *im Grossen*. This was, perhaps, his most important and successful work. His attack on the four-colour map problem was not successful in spite of intensive study and effort but it inspired others like P. Franklin to make their own important advances. In mathematical physics his book on relativity and modern physics deserves to be far better known than it is; though it came rather late in the relativistic day, his contributions there have been regarded as important by no less a geometer than Levi-Civita. If he did not follow up the enticing field of tenser analysis, it must undoubtedly have been because the Princeton school (which he himself helped found with Veblen) had plunged into the heart of the subject with greater vigour and success than could have been expected at that time by a solitary research worker whose main interest lay in other branches of mathematics. Birkhoff's proof in 1931 of the ergodic theorem was due to his having gone first to the main point of the topic towards which such capable workers as J. von Neumann were also converging. The actual flawless proof was supplied a year later by the Soviet mathematician Khinchin in a definitive paper which is at the same time a model of graceful tact; but the basic ideas derived admittedly from Birkhoff who showed the fundamental position of the concept of measure and integration, particularly of Lebesgue integration, in such problems. On the other hand, I find it impossible to take Birkhoff's "Aesthetic Measure'' seriously.

Authoritative and complete obituaries will rewritten by those who knew Birkhoff much better than the present writer, and whose mathematical stature could be said to equal his in some directions at least. One can only point to Birkhoff here as an important subject for study in the development of science in a country which changes over rapidly to an advanced mode and

greater concentration of production. The precise function of the individual can only be studied against the background of the changing system, and this is generally not done in obituaries of the type to which we are accustomed. India must some day take the lead in a similar way - though a tremendous expansion of business is now going on in this land without the corresponding scientific advance one should naturally expect, for the simple reason that our intellectual life is still disoriented and based (even debased!) upon concepts originally derived from the scanty overflow of a colonial economy. If an answer is wanted some day as to why a real school of Indian mathematicians (did; or) did not develop after the second world war, the historian of science could do worse than study the development of Birkhoff as a facet of the development of his country. He used to mention in moments of confidence (expressing amusement mingled with slight but noticeable regret) that a Dutch relative of his had offered him an active share in a cable company, and had the laugh of him ever since by making a fortune out of the enterprise to which Birkhoff had preferred the obscurity of a simple professorship! One wonders what had happened to the Dutch cousin and the cable business by the end of 1940. But that must have been a year of disappointment for Birkhoff too, for the international mathematical congress scheduled for Harvard that year had to be cancelled because of the war. It would have been an occasion to round out his whole career, an occasion upon which he could see his students carry his country to the forefront of the science to which he had devoted his entire life, giving up all the financial opportunities that were open to any American of his mental powers in the period of expanding bourgeois capitalist economy. One wonders whether the war had changed Birkhoff's naive views about the importance of race and the essential glory of Nordics, which he held very strongly at least till 1934. Did he realize that "pure Anglo-Saxon" was even more meaningless than "American scholar" had been before him, and that "American" was not a race but a mentality? It shows the fundamental nobility of his character that he never allowed such views to interfere with his scientific judgment, nor to prejudice him in the slightest in the matter of adjudicating research fellowships and prizes. He had no hesitation in recommending for important posts people with whom he was not and did not want to be on visiting terms. It was noticeable that when he expressed his views on politics or sociology in any sort of mixed company, anyone could (and someone often did) contradict him flatly without offence on either side. But the moment he began to talk about mathematics, the others (no matter what their specialty) quietly stopped their own chatter to listen. It was impossible not to love such a teacher.

In the lifetime of any scientist who has not the good fortune to die young, (like Abel, Galois, Riemann, Ramanujan) there must inevitably come a moment when he begins to sense his own limitations, to feel the joints of his mind stiffening no less than those of his body, to shrink a little from the thought of testing his ability against totally new problems. Far too many scientists of first rank then go the way of popular acclaim, newspaper reputations and public performances, to drown the insistent voice from within which begins to ask "the end is near, you are going down the intellectual slope; how much of your work will survive? What is your share of immortality?" If Birkhoff had any inkling of the end, one feels that he would have faced it without a qualm, for his work was safe (in spite of wartime regression) in the hands of the American school. His great contemporaries greater in absolutely effective total scientific achievement as for example) Hilbert, Levi-Civita, Lebesgue could not have had this assurance of continuity dying as they did in the midst of universal distress and the collapse of all they bad been brought up to honour. In this, Birkhoff was fortunate above the rest, and none deserved such fortune better.

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