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SCIENCE
AND INDIAN CULTURE

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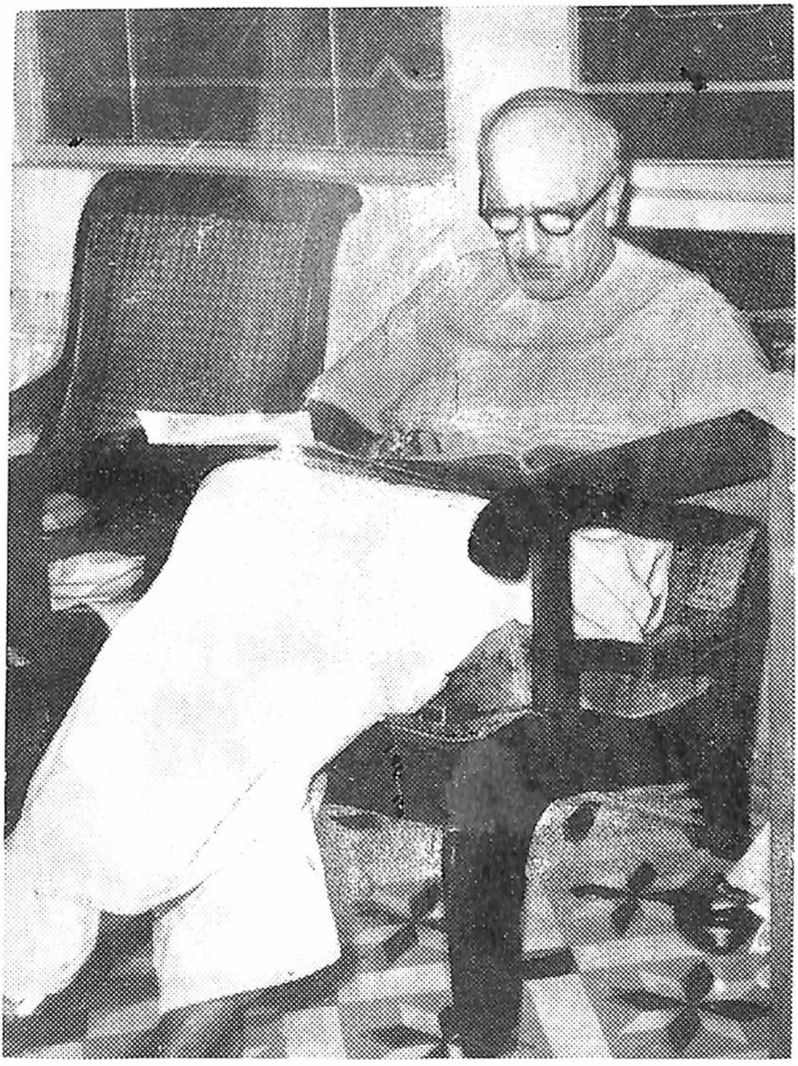

J. B. S. Haldane (1892—1964)

SCIENCE AND INDIAN CULTURE

J. B. S. HALDANE

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MY DILEMMA

I have now been in India for two months and can begin to review my position. I cannot undertake systematic teaching, nor begin certain kinds of research, until my papers, books, lantern slides, and so on, arrive by ship. But I have magnificent facilities for other sorts of work at the Indian Statistical Institute, and I am not using them properly.

This is partly because I have had some slight illnesses, partly because I am a lazy old man, and the monsoon weather in Calcutta, though delicious, is not invigorating. But the main reason is this. I spend a lot of my time in answering letters. I naturally expected a number of letters on arrival. Most of them welcomed me most warmly. But I was very glad to get two which told me to go back to England. They were a most pleasant change, and I hope I answered them politely. Unfortunately the rate at which I receive letters shows little sign of falling off.

So I am in a dilemma. If I do all the things asked me I shall have no time for my work here, and in a year or two the Institute will regretfully terminate my appointment. If I answer no letters, or refuse all requests, I shall get such a reputation for rudeness that I may also be requested to leave. Let me therefore plead with my correspondents.

I get a few begging letters and even telephone calls. I am sure some are genuine. But among thirty-eight crores of Indians there are certainly more than thirty-eight thousand liars. I have always given away some money to people poorer than myself. But in my experience those who need it most ask for it least. In India those who need it most cannot afford a stamp and can rarely write. I get numerous requests for jobs. Now one reason why I have come to India is that I wish to escape responsibility for appointments, and other administrative work, in order to do research and teaching. I fear that my correspondents cannot imagine that this is true.

Numerous people wish to converse with me, and even visit the Indian Statistical Institute in order to do so. As I receive a salary from this institute, it would be wrong to stop work to talk on anything but science or mathematics. But I have another, perhaps more selfish reason. I genuinely enjoy solitude, either watching living animals and plants, or doing calculations on paper. In this I at least share the tastes of the millions of Indians who, in the past, retired to forests at my age. Some of my visitors wish to converse with me on religion. Can they not remember that most highly religious people have loved solitude ?

Next there are the people who send me manuscripts and typescripts to read. Exactly one of these, a description of Indian birds, has struck me as really good. Most of them display a fantastic inaccuracy whenever a statement is made which purports to be scientific. I have the choice of being rude to their authors on trying to teach them elementary science by correspondence.

Finally there are the ladies and gentlemen who invite me to be away for two or three days to give a single lecture, or to be the guest of honour at a feast where I shall be expected to speak for fifteen or twenty minutes. I think that if I can help a few Indians, perhaps only one or two every year, to start a life devoted to scientific research, as I have helped others in England, I shall be more use to India than by allowing thousands of people to see and hear me for a short time. Even when I am invited to a university, my time is largely wasted. I am asked to give several talks to different groups of students. They can learn little from these. By all means let me appear on a platform for five minutes for those who wish to see me and hear my voice. But then, if we are staying there a week, let my wife and I each give five lectures or so to small groups to whom we can describe recent developments of science which have not yet got into the text books. And do not trot us round laboratories where work is done on subjects of which we have no experience. Give us the time to talk with a few colleagues, preferably junior workers, with whom we shall have common interests.

I have already come to one conclusion as to why science in India is developing with disappointing slowness. It is not because Indians are stupid or lazy. It is because they are too polite. They spend hours daily in conversation with others, not on professional matters, but on personal topics. In London I talked with colleagues for an hour or more daily, but it was mostly about the details of our work. In the Indian Statistical Institute the same is true. But it is not true in most academic institutions where I have been in India. Again at scientific meetings and usually in ordinary discussion my Indian colleagues are polite about one another's work. In Europe we are usually polite about the work of juniors, and highly critical of that of men and women of established reputation. At a recent international meeting on genetics an American got up after a paper by my wife and said that he could not let her highly misleading views pass without criticism. She felt that she had at last reached the status where one is criticized without mercy. She and I at once formed a friendship with the critic. We had something to talk about. In my opinion only a few branches of Indian science have reached the stage of maturity where this is possible. I may criticize some of my colleagues as I would criticize British colleagues, and hurt their feelings severely. Once again I am up against the choice between politeness and efficiency. I do not know how I shall resolve this dilemma. I hope that as Indian science grows up, it will become less acute.

Meanwhile this article may serve to explain, if not to excuse, what many people must regard as my gross discourtesy.

INDIA AND THE COMMONWEALTH

I write on this topic only at the request of the editor, and even so with considerable trepidation. I have just taken up Indian domicile, but it will be several years before I learn to think of myself as an Indian. Even then I shall have to be careful of seeming to give advice to Indians. To do so to-day may be foolish as well as tactless. I cannot yet see international problems from an Indian point of view, though of course I am trying to do so.

I feel a further reluctance to write owing to the title of this journal. Asia is not united. Its peoples are pretty broadly agreed in their objection to European and American colonialism, but in nothing else. The moment they achieve liberation they show their lack of unity, as witness the tragic quarrels between India and Pakistan, and between different parts of Indonesia. Surely a prerequisite to clear thought on Asian affairs is a recognition of the great diversity of Asian cultures. The different cultures of India have enough in common to allow unification, as in the small European country of Switzerland where three main languages are spoken, besides several local dialects, and two different types of Christianity are practised. But the cultures of China and India are fundamentally different, though not of course antagonistic. For generations to come India and China can, and I hope will, achieve friendship and cooperation, but hardly unity.

The position of India in the British Commonwealth is surprising. Although much (but by no means all) of India had been conquered by the British, India did not leave the

Commonwealth on achieving independence, as the Irish Republic and Burma did. On the contrary, it has a larger population than the rest of the Commonwealth combined. There is good reason to hope that in A. D. 2000 India will have achieved an economic level not very different from Britain's present level. If so, if it remains in the Commonwealth, India will be its most powerful member. Traditionally minded British politicians will find this intolerable, and there will be a movement in favour of British secession from the British Commonwealth.*

I can quite understand the attitude of Indians who wish to quit the Commonwealth. If I were an Indian I should very likely be one of them. For I have stronger emotions about national independence than most Englishmen. One reason why I left Britain was the presence on British soil of American troops. Nevertheless I am inclined to think that, for another ten years or so, India will benefit from Commonwealth membership. Every British Government will exert itself to prevent an armed conflict between members of the British Commonwealth. If India seceded from the Commonwealth while Pakistan remained in it, certain adventurist groups in Pakistan would, I believe, be much more likely to start hostilities than they are to day. Similarly I think, for the present, that membership of the Commonwealth is an asset to India in dealings with the United States of America. Ten years hence, even if the Second Five Year Plan is only partly fulfilled, India's industrial position should be strong enough to allow secession without danger, if it is desired. Again for the present, I think it pays India to remain in the sterling area. If British Governments are guilty of even a few more actions like the invasion of Egypt last year, the financial position of sterling will be such that India will be well advised to dissociate the rupee from sterling. I also think that, for the present, India gains culturally by association with Britain.

* The British Government has already, in 1962, started this movement by trying to join E. C. M.

Of course cultural contacts would continue if India left the Commonwealth, but they would be more difficult.

However these arguments may be biassed by the fact that I am overwhelmingly convinced that the presence of India in the Commonwealth is in the interests of the British people, and this for four different reasons.

If the British and French expedition to Egypt in 1956 had developed into a full scale war, it is highly probable that both India and Pakistan would have left the Commonwealth. The possibility of such a secession undoubtedly weighed with many conservative politicians. Their objections to secession were no doubt largely sentimental. But they are real. And as Ghana and other self-governing African states join the Commonwealth, it will become clearer to conservative politicians that British foreign policy will have to be designed to keep it from falling apart, even at the cost of "British prestige," which is in any case a pale ghost of the reality of a century ago.

While Pakistan, Ceylon, and Ghana will pull British policy in the same direction against colonial wars and the like, India has, for the present, a unique part to play in the Commonwealth, because it is the only member which has definitely chosen the socialist path. If the Second Five Year plan is even partially successful, this will have a considerable influence on the British Labour Party. A large group within this party is far more concerned with improving the economic and social status of workers under capitalism than with building socialism. I am a socialist, and believe that economic progress is far quicker under socialism than under capitalism. Further I do not believe that socialism can only be achieved at the cost of suppression of civil liberties which characterised Stalin's rule.

Some British socialists do not believe that India will be able to achieve socialism without a great deal of outside help. I think that it probably will with no more foreign aid than can be obtained through normal channels. If, five years hence, India has flourishing state owned steel and cement industries, to mention no more, this will have very great political repercussions in Britain. Large members of British politicians, economists, and technologists, will come to India to see how socialism is working. If, ten years hence, Indian bustees have not been cleaned up, you may look forward to reading lurid accounts of them in the British press in which they are described as the horrors of socialism. As a socialist, I want India to stay in the Commonwealth to lead its other members to socialism.

Few countries in the world will suffer more severely than Britain if a third world war breaks out. Hence there are few countries where Gandhi's policies are more obviously in accord with enlightened self interest. There is a pacifist movement in Britain, but it needs strengthening. I should like to see Gandhism actively preached and practised in Britain. A satyagraha movement designed to stop both the manufacture of atomic bombs and the presence of American troops could, I believe, succeed. And in my opinion its success would mean a very great increase in security for the British people. So long as Britain and India remain in the same Commonwealth the possibility of starting such a movement is considerably greater than it would be if this link were broken.

Finally there is an intellectual reason. Five centuries or so ago the educated people of western Europe rediscovered the pre-Christian art and literature of ancient Greece and Rome. This event was called the Renaissance or re-birth. They did not abandon Christianity to worship Jupiter (Indra), Minerva (Sarasvati), and the other "pagan" gods. But they allowed the ancient mythology to penetrate their imaginations and the ancient philosophies to influence their thought. I believe that Europe is ripe for another renaissance based on Hinduism. I do not think that many Europeans should be, or will be, converted to that religion. But I want its mythology to influence their childhood, and its philosophies their adult lives. I personally was told a doubtless very simplified version of the Ramayana by my mother. The one character who stuck in my mind was Hanuman. Hanuman slightly enlarged my childish imagination. I felt that I could serve a hero as he served Ram. If I had learned more such myths my imagination would have benefited further. I do not believe that any philosophers, whether in Europe or Asia, have fully answered the questions which they asked. But I am convinced that some Indian philosophers have come as near to truth as any outside India, and that it is ridiculous to neglect them.

If Indian thought and feeling are to fertilize the European mind the more political contacts can be kept, the better, provided they are on a footing of equality. So my last word to those Indians who wish to leave the Commonwealth is this : "Please believe that by remaining in the Commonwealth, even if it is irksome to you, you may be performing a great service to its other members, and through them, to the whole world."

THOUGHTS ON THE LANGUAGE QUESTION

It is difficult for a person whose native language is English to write impartially on the problem of what language should be used in India. I shall try to do so, but it is doubtful whether I shall succeed. I sympathize with Indians who wish to get rid of a language which was imposed on their ancestors by force. But to do so at once in the field of technology and higher education would put back the scientific and economic progress of India for at least thirty years. The case for English in scientific education was a great deal stronger even ten years ago than it is now. Since then the United States and Great Britain have capitulated to the Soviet Union by their refusal to pay for scientific education and research on a sufficiently large scale. Already there are better text-books in the Russian than in the English language in several branches of science, and they are very much cheaper. Ten years hence the lead is likely to be increased. I certainly recommend Indian students of science to learn Russian. I do not, of course, suggest that Russian should replace English in Indian universities. I do say that the case for retaining English is not so strong today as it was ten years ago.

But given the present historical situation, we may reasonably ask, "Is it beneath the dignity of a free people, and is it efficient, to teach and think in a foreign language, the language of a conqueror ?" Here the history of Europe will help us. Southern and Western Europe were conquered by the Romans, the conquest being nearly complete 1900 years ago. The Empire collapsed in the fifth century A. D.. Nevertheless Latin, the language imposed by the Romans, was used for education, law, and religion for another thousand years, even though the Being who was worshipped in Latin was cruelly killed by Romans, and perhaps never spoke a sentence in their language. It was used not only by those whose ancestors had been conquered, but by peoples like the English and western Germans whose ancestors had invaded the dying Roman empire.

Long after there was quite a vigorous English language, Latin was used in administration and law. The importance of Magna Carta, which King John of England was forced to sign in 1215 A. D., may have been exaggerated ; but it was certainly important. It was written in Latin, and in Latin more atrocious* than any English which I have encountered in India. Newton's "Principia" was written in Latin less than three hundred years ago, and in my opinion is the most important book ever written in England. The English had already begun the conquest of India before they discarded the language of the men who had conquered Britain sixteen centuries earlier. One cannot read an Indian newspaper today without coming across Latin phrases such as ultra vires which have survived in English law with meanings which an ancient Roman would barely have recognized.

Newton wrote the Principia in Latin for two reasons. Few people could be expected to understand it. Most of these lived outside England and could not read English. And Latin had developed a considerable precision, the more so perhaps because its use had been confined to educated men for a thousand years. English was vigorous, but was developing rapidly, and was rather short of abstract words. However in Newton's time scientific books were already being published in English, and the "Opticks", which he wrote in his old age, were in that language.

But long after Newton's time English education was based on Latin. I belong to the last generation so educated, and my

* "Nemo vel imprisonetur vel utlagetur vel alio aliquo modo destructur..."

Latin was rather little use to me. For it was not used to teach me science, history, or geography. Nevertheless I had learned it thoroughly enough to take notes in very bad Latin of university lectures given in English. Perhaps I was the last English boy to do so, fifteen centuries after the last Roman soldier left Britain.

Now I do not suggest that Indians should go on using English as a main feature of their educational system for fifteen centuries, or even for a hundred and fifty years. I do suggest that there is nothing shameful in using it for another generation or so. Unless some artificial language is adopted all over the world, which seems to me less likely now than it did thirty years ago, English will doubtless be replaced, for scientific purposes, by an Indian language. Sanskrit is a possible candidate, but I think its adoption for this purpose would probably mean that many of its words would change their meaning, and the classics, particularly the philosophical texts, would become harder to understand with each passing year.

I do not know whether Hindi will develop quick enough to enable it to take over from English. I certainly do not agree with all the critics of Hindi. It seems to me an easy language to learn. The fact that verbal forms vary with the gender of the subject, as they do in Arabic, never worried me. I don't even mind the fact that the same vowel sign means one thing before a consonant, and another after it. This principle is, I think, more useful in arithmetic than in spelling. Nevertheless the present script is inefficient. Men who have learned to read Hindi or Bengali before English can read English station names at a greater distance than those in the Indian scripts. We in western Europe had the same trouble. When reading was the monopoly of a few learned men we developed a formidable system of contractions, conjoint letters, and so on, and of needless flourishes on English letters. Within less than a century of the introduction of printing in Europe the printers in Italy had adopted letter forms based on ancient Roman inscriptions. These did not include any contractions. Gradually handwriting was simplified to conform with printing, and it became easier both for children and adults to learn to read and write. Some minor changes have recently been made in Devanagari printing. But I believe they will have to go a lot further before this script is as easily read and written as the west-European script.

Still more serious is the question of the vocabulary. If Sanskrit roots are adopted throughout it will be extremely difficult to find expressions for the various scientific and technological notions which are expressed in the modern European languages. If Sanskrit roots are used to express ideas foreign to ancient Indian thought future generations will find it progressively harder to understand that thought. The English language uses Anglo-saxon, Greek, and Latin words, along with a fair amount of Hebrew and Arabic. Some of our most beautiful words, such as "paradise", are of Persian origin. A hundred years or so ago there was a movement to use Anglo-saxon roots, and, for example, to call an omnibus a folkwain. This was a complete failure, while similar movements in Germany and Tamilnad had more success.

I believe that whatever lexicographers at Delhi may decide, Hindi will incorporate words from other languages. The more languages are available, the more shades of meaning one can achieve. For example "sympathy" is derived from two Greek words, "compassion" from the corresponding Latin ones. If objection is raised to European and Persian words, Tamil and the other languages of Southern India have very rich vocabularies even though they have absorbed many Sanskrit roots. Whatever the constitution may say on the one hand, and speakers of other Indian languages on the other, I believe that the success of Hindi is likely to depend on its adaptability, and that those who are trying to keep it "pure" are making it less and less likely that it will be learned all over India.

Hindi will only become the second language for all Indians if its supporters are prepared to compromise. Whatever efforts they make, it will change. You cannot keep out foreign words as you keep out foreign manufactured goods. Perhaps Telugu accepts them more easily than any other Indian language, and this will certainly help to make it a rival to Hindi in teaching science, medicine, and engineering.

I do not know what the result of the present controversy will be. I do not even very greatly care. If everyone in India learns to speak one language it will certainly make things easier for foreigners. But in Europe the highest cultural level is reached in small countries such as Denmark and Holland whose people speak their own languages, though most of them have learned English. The obsolescence of any of the main Indian languages would, I suspect, be a setback for culture even if it made the dissemination of science a little simpler. But I hope that the argument will be fairly conducted, and that I shall not again read the plain lie that no independent people has conducted its government and culture in a foreign language.

THE NEW CASTE SYSTEM

I must apologize for this title. But I used this phrase in the first five minutes of a lecture on European classical literatures, and I can quite understand why the reporters went to sleep during the rest of it, even though I think I may have made a few remarks which could have interested them had they been awake, for example as to translations of the Bhagavadgita into various European languages. My remarks on the caste system were, however, all that got into many, at least, of the newspapers.

In the opening sentences I felt that I had to justify myself for giving such a lecture. I pointed out that my only academic degree obtained by examination was in Litterae humaniores, commonly called Greats, at Oxford. This examination is based on the study of philosophical and historical works in the ancient Greek and Latin languages. I have no degrees for research, and no scientific degrees except honorary ones. But as I have also an honorary doctorate of Laws, this hardly means much. I am therefore, by the standards of Indian universities, qualified to teach Greek, Latin, and perhaps philosophy or even history, but not to teach any branch of science.

I have just declined a request to propose a candidate for a professorship of statistics in a certain university because the qualifications included a degree awarded for research in mathematical statistics. I know many of the world's leading statisticians, and very few of them have such degrees. They improved statistical practice because they had to deal with large numbers of observations about atoms like S. N. Bose, jute yields like P. C. Mahalanobis, heights of human beings and their relatives like R. A. Fisher, earthquakes like H. Jeffreys, and so on. They had degrees, but not in statistics.

Some one might, however, say that statistics were a special case, being a very young science, but that in the older sciences such specialisation was needed. This is utter nonsense. Let me take some examples. Professor P. A. M. Dirac is Professor of Mathematics at Cambridge. He might equally well be called a professor of mathematical physics or even of statistics. He took his degree in engineering. On the continent of Europe many of the professors not merely of such sciences as physiology and anatomy, but of zoology and botany, have medical degrees only. At University College London the professor of anatomy, J. Z. Young, has a degree in zoology. He had not dissected a human corpse systematically until he got his present post, though he had made distinguished contributions to human anatomy by his work on the healing of severed human nerves. I could go on almost indefinitely.

The reason for this state of affairs is simple. An outsider often sees what needs doing in a science better than one who has specialised in it. For example my father, whose only degree was in medicine, became among other things Professor of Mining at Birmingham University, and President of the Institution of Mining Engineers. This was because, as the result of work on human breathing and on ventilation of houses and factories as well as mines, he saw how to make revolutionary changes in the system of ventilation in mines, which not only improved the health of coalminers but lessened the danger of fires and explosions.

In India it appears to be necessary to have a degree in a subject before one can teach it in a university or even a college. This requirement is perhaps most utterly ludicrous in the case of the various languages spoken in India. A friend of mine was refused a post to teach his native language because he had no degree in it although he had published a fair amount of verse in it which many people regard as poetry. He has a degree in another subject. But even more fatal is the practice, which prevails in one university at least, of refusing to accept a student for the M.A. course in any science unless he has taken a B.Sc. degree with honours in that particular science. This is calculated to ensure, so far as is possible, that Indian scientists will be specialists, whereas men like Jagadis Bose, Meghnad Saha, and Prasanta Chandra Mahalanobis have achieved eminence precisely by bridging the gaps between different sciences.

When I refer to this requirement, I am told that the teachers merely insist on preliminary knowledge which is necessary before a student attends an advanced course in a subject. I have never heard this argument from any of the teachers of science whom I respect, and I do not think that they are less willing to recruit good students for this subject than were my colleagues in England. Certainly if I were teaching botany I should insist on high academic qualifications from a student who wished to switch over from chemistry or zoology. But a man or woman who has done sufficiently well in a preliminary examination in one subject is likely to do well on switching to another. In particular he should be able to guess whether he can get a first class in spite of the extra work involved in covering the elementary part of the subject. A person with such double qualifications is far more likely to make serious contributions to research than one with a single qualification only.

Of course a chemist or geologist, so labelled, will not transmit his caste to his sons, nor will he be forbidden to marry the daughter of a historian or even of an outcaste without a degree. So far the new caste system imposes less serious restrictions on human choice than did the old one. Nevertheless it will lead, and in my opinion is already leading, to a considerable loss of human possibilities.

Associated with the caste system was the prohibition of overseas travel for members of the higher castes. It seems that an attempt is being made to revive this, though so far in a modified form. I understand that the Ministry of Education has recently requested university authorities and members of universities not to approach "foreign missions etc." for the award of any scholarship, but asks that all approaches should be made through the Government. Apparently foreigners are also expected to conform.

In fact the most satisfactory awards are made somewhat as follows. Professor Gilchrist (which means servant of Christ in Gaelic, the ancient language of Scotland) asks his friend Professor Lakshmandas if he knows of any students who would be likely to do useful research in his laboratory. After some correspondence they agree that Sri Hanumandas is an appropriate person. Professor Gilchrist approaches the Midas Foundation, and Professor Lakshmandas approaches Vice-Chancellor Ramdas, so the whole matter is arranged. Professor Gilchrist is not going to get the Midas Foundation to write to Sri Kautilyadas in Delhi, asking him to find a suitable person. Professor Lakshmandas may be the only person in India who understands enough about the work to be able to make a recommendation. Or so at least Professor Gilchrist thinks, having had an unfortunate experience of an Indian student with a good record in examinations and excellent testimonials. Perhaps Mr. Hanumandas did not even secure first class honours, or did not secure them in the right subject. If so it will be hard to get him recommended by Delhi. The net result is that Professor Gilchrist gets a student from Finland, and one more young Indian is debarred from crossing the *kala pani* I am quite aware that the Midas Foundation is associated with shady foreign financiers and shady politics. But if we are to accept any foreign aid of this type we cannot be too critical about its sources. And I think if there is corruption in such connexions it is quite as likely to occur in new Delhi as in a University.

The specialisation of Indian scientists has already gone so far that they are held in slight contempt both by literary or artistic and administrative workers on the one hand and by doctors and engineers on the other. I have been told "You are not a scientist, you are an intellectual". In England we are quite well aware of the danger of such specialisation, and in our better universities we manage to avoid it. For example in the department of zoology at University College London, where I worked, the professor, D. M. S. Watson, was not only a world famous palaeontologist and comparative anatomist, but an expert on early Chinese grave furniture of which he possessed a fine collection. The students were of course more specialised in some years than in others, but I remember one year in which, by sending postcards from various different parts of London, they induced the British Broadcasting Corporation to produce a particular piece of music. The class in question included some unusually good zoologists, one of whom is certainly qualified by everything but a degree to be a professor of physiology. Incidentally one of the lecturers in the same department took a degree in geology and none in zoology, another took a degree in engineering and practised as an engineer for some years before taking a degree in zoology.

I have kept my most serious criticism to the end. It is a regrettable necessity that in a few professions such as aeroplane pilots and surgeons, to whom others entrust their lives without examining their past record, rigid qualifications are necessary. And their enforcement in other professions is not unjust, though it may be inefficient, in a state where education is free at every stage for those who can pass the tests for entering that stage. But it is grossly unjust in a country like India, where I do not think that one father in fifty can afford to pay for a full university education for even one of his children, and scholarships on which a student can live are extremely rare. When this was the case in England plenty of scientists, such as Priestley, Davy, Faraday, and Wallace, not only did first rate work, but achieved full recognition, and often substantial salaries, without any academic qualifications. Such cases are very rare in India. I can think of one man with no degree who earns his living by research, and is constantly invited abroad to scientific conferences. However, his pay is far less than that of workers with degrees and no record of first-rate work ; and as regards university teaching, he is an untouchable.

The old caste system had this merit, that the richest merchant or zamindar could not buy the status of brahmin for his son, even if the son was learned and pious. Whatever the defects of that system—and I think that they were and are grievous—it was not subservient to wealth. The new caste system which the university administrative authorities, with the connivance of many government officials, are trying with some success to impose upon India, has no such excuse. I hope that steps may be taken to break it before it exercises the same paralytic effect on India as the old one did in the past.

THE SCANDAL OF THE SCIENCE CONGRESS

I was privileged to hear the Prime Minister's speech to the Association of Scientific Workers at the Science Congress recently held in Bombay. I did not hear his address to the Congress as a whole, since my ticket for this event had been thoughtfully removed from the booklet issued to me on arrival in Bombay. The Prime Minister made some rather bitter remarks about Indian Scientists who worked abroad because pay and facilities were better. Of course such statements have some relevance to my own case. I have left England for India because the facilities for scientific research are much better, though my salary is only a little over half what it was in London, and what I could still be earning had I remained there. Perhaps some Indians remain abroad for the reasons stated by Mr. Nehru, but others (including all of whom I have met) do so for very much more honourable reasons. Every scientist who is worth anything has a double loyalty, to science as well as to his country. In India there are numerous laboratories where scientists are forbidden to work. I can think of one in Calcutta where a worker drew Rs. 400 per month for at least six months without doing anything but filling in forms about work in contemplation and showing visitors round. The worker in question could have done some research, not probably very important, but was ordered to remain in the laboratory beside an incomplete apparatus, and explain the project to visitors. This is not an isolated case. All over the country junior workers are regarded with jealousy by their superiors, who either discourage originality or steal its results. I recently saw a bibliography of publications by the head of a well-known Indian laboratory. This remarkable man had published over fifty scientific papers in one year. No single human being before him has ever made discoveries at this rate ! No doubt junior colleagues had done most of the work, or all of it. But their names were not mentioned. It is not surprising that young men do not care to work under such conditions, particularly, if, like the unfortunate agricultural scientist who recently hanged himself in Delhi, they are forbidden to apply for posts elsewhere. So long as the Government Departments concerned do nothing to discourage persons responsible by cutting down grants, and by other methods which are available to them, bright young men will take jobs abroad. The Prime Minister himself is not wholly free from responsibility. He has certainly given his blessing to laboratories which produce very little work of any value, and use up a lot of foreign exchange, while training young men very badly indeed.

At Bombay the Science Congress appeared to be an organized conspiracy against originality in Indian Science. I received a fat volume of summaries of papers to be read in various sections. I selected twentyfive papers to be read in eight sections as being particularly interesting. Sometimes I should certainly have been glad to hear the full details. In at least three cases it was clear that the author did not know some facts which I knew. Five minutes' talk with me might have saved him or her five months' work. The so-called programme issued to members merely stated that papers would be read in a particular section, say Engineering or Zoology, between certain hours. This was not always the case. Sometimes a discussion was arranged at the time when papers were supposed to be read. Even when the president of a section adhered to the times given in the programme the order of the papers was quite unpredictable.

I had asked, both in my own name and in that of a distinguished foreign visitor, that the custom normal in Britain, U.S.S.R., U.S.A., France, Germany, Italy, Sweden, Japan, and other countries where I have been to scientific meetings, might be followed. This is to adhere, so far as possible, to a time table which is issued to the persons attending the meeting, and to put up public notices of any deviations from this programme. As this was not done, I did not manage to hear a single one of the twentyfive papers which I have mentioned. In consequence the meeting was of little use to me, and I was of little use to Indian science.

Let me make the position as clear as I can. The two addresses of sectional presidents which I attended were excellent summaries of our knowledge of one branch of Indian geology and one branch of soil science. They were not announcements of new discoveries. The special and popular lectures were often excellent. They saved their hearers the trouble of reading accounts of research in journals, which are often hard to find in India. But they did not give me a chance of hearing and seeing the young Indians who are actually advancing science. The whole set-up of the Congress is an example of the repression of young workers by their seniors, which is one of the most regrettable features of Indian science, largely responsible for the flight from India which the Prime Minister rightly deplores.

If he wishes to stop it, one step which he can take at once is not to attend a science congress again until this injustice to the rising generation is remedied. I am told that he complained of the lack of shade in the pandal. Had he attended any of the lectures delivered there, he would have had a good deal more to complain of. The lantern was almost absolutely useless. I was in the second row of the audience during the lecture on elementary particles by Professor Abdus Salam, a Pakistani who has recently been given a chair in London. Many of his slides could not be read. I do not suppose that even one could be read by people in the back rows. If no adequate lantern is available, the lecturer should be told so.

He can then either prepare a lecture which does not require a lantern, or refuse to lecture. The microphone in the pandal was fairly efficient. Both the lantern and the microphone in the hall of Kishenchand Chellaram College were highly inefficient, and one very distinguished foreign lecturer was quite inaudible. If the organizers of the congress took science seriously they could have provided these facilities at far less cost than the coloured lights, variety entertainments, and so on, on which the money of donors was spent.

Besides the sectional meetings there were supposed to be a number of discussions and symposia. One of these, on "Modern trends in the study of physical anthropology (human biology) with special reference to India", attracted some fifty members. After they had waited fifteen minutes they were told that it would not be held as its convener had been called to Delhi. Those who were so ill-advised as to attend the meeting on "The structural basis of cellular differentiation" were not even told why it was not held. An hour was wasted on the international society for tropical ecology. I did not attend this as I was attending a sectional meeting, and had no wish to hear what distinguished politicians had to say on ecology. As however I am interested in the subject I was one who attended its first meeting. None of its officers turned up, though the congress officials in the building where it was supposed to be held had received no information that it had been cancelled. In order to attend this meeting I had refused to join a party visiting the caves at Elephanta.

The root cause of all this incompetence and worse is not far to seek. A large number of Indian scientists have no pride in their profession, though they are proud of their salaries and positions. The opposite attitude is common in Europe, as it was in ancient India. I have seen a member of the council of the Royal Society (R. A. Mc Cance, to be precise) turn up at a council meeting in shabby clothes with his luggage on his back in a knapsack. In India today the unworthy successors of Durvasa and Visvamitra actually invite governors, vice-chancellors, and the like, to address them. This may be a relic of British rule. If so it is a regrettable one. I am quite aware that some British scientists behave in the same way, and that some of the most distinguished Indian scientists do not, and consequently do not appear at meetings of the science congress.

It is time that responsible persons in India realised that the invitation of foreigners to such congresses lowers the prestige of Indian science considerably. So do the tours arranged for them later. They are too polite to express their feelings to their hosts, but not always too polite to express them to me. I give two examples from this year's tours.

One foreign scientist was permitted to visit one of the four laboratories in India where internationally famous work in his subject is done. But he had to visit at least six where the work is of a very poor quality, but the university and other authorities have influence with those who arrange such tours. Another visitor, Professor Martinovic, a well-known European zoologist, spent 4 days in Calcutta, but no time was allotted for him to visit its Zoological Garden. I took him there from 5-30 to 8 a.m., and he told me that he had never admired any Zoo in the world so much. He made no comment, favourable or otherwise, on the numerous institutions in Calcutta to which visits had been arranged for him. No doubt a person who devotes himself to his job, and whose institute is worth seeing, has little leisure to approach the persons who produce the programmes for visitors.

I do not wish to be unfair to those who made arrangements at Bombay, and I wish to state the accomodation and the breakfasts in the hostel attached to the department of Chemical Technology, where I stayed, were better than in some quite expensive hotels in Bombay where I have stayed in the past. The vegetarian food provided near the pandal was also simple and good.

But the object of the Science Congress should be to advance science in India, and this, in my opinion, it failed to do. There would be little difficulty in making it useful. This would involve discourtesy to some influential people. But in science efficiency is more important than courtesy.

WHERE SHOULD OUR SCIENCE STUDENTS GO TO ABROAD ?

Every year hundreds of Indian students of science go abroad hoping to return as Doctors of Philosophy. I am absolutely opposed to this practice, and regard a foreign degree as a point against any one who wishes to work with me. But I am aware that such degrees are a help in obtaining posts in universities and elsewhere in India. In the three universities where I worked in England, namely Oxford, Cambridge and London, we were sufficiently confident of ourselves to ignore degrees. Men and women were chosen for academic posts mainly on their published work and their record as teachers. It was unusual, though not unique, to get a series of professorships, as I did, without any scientific degree at all. It is quite common to take a degree in one science and do teaching and research in another. I hope to see this common in India also. One reason why Indian graduate students wish to go abroad is a very simple one. They are systematically humiliated by the administrative staff of many institutions, and sometimes by professors, in a manner which is not tolerated in western Europe or the United States. Again I hope to live to see this remedied.

The students who should go abroad are those who will benefit most from foreign study. These are young men and women who have done research in India which has brought them some international recognition. They know enough to know their own ignorance ; they know where they can learn what they need for their further work, and they are in a position to be welcomed by the leaders of research in their own field abroad. Perhaps they want to study forest tree breeding with Gustafsson in Stockholm, the formation of bacterial enzymes with Monod in Paris, or invertebrate embryology with Ivanov in Leningrad. They have done enough to find no difficulty in securing a place under one of these masters.

The other type of Indian scientist who should go abroad is one who has no university degree at all like Srinavasa Ramanujan, or only a general B. Sc., and whose advancement is completely blocked in India. If he or she has done even a little research, this is strong evidence of ability and interest in science. Such people, even if they are not quite first rate, should be helped to get foreign degrees, so that they can get the posts which they deserve in India.

Those who actually go are often quite unfitted for research, however well they may have done in examinations, and neither learn how to do original research, nor are a good advertisement for their country. However if they are to go abroad, where should they go ?

The fact that Indian students have learned their science through the English language, as European students learned it through Latin three hundred years ago, makes higher study in Britain, U. S. A., Canada, and Australia, relatively easy. But study in rich countries is dangerous, for the following reason. Their laboratories are well equipped with expensive apparatus. A man who has learned how to use an electron microscope or a "Maser", as a particular type of micro-wave apparatus is called, and not much else, will be of no use in India unless he gets into one of the very rare institutions which possesses one. He will be just one more frustrated Indian scientist, or if he is good enough to get a permanent post abroad, one more expatriated Indian scientist.

However a ~~good deal~~ of first rate research, even in physics and chemistry, is being carried out with apparatus which can mostly be made in India. For example a study of the growth and mechanical properties of crystals is of the greatest importance for metallurgy, and very important work has been done in this field by Verma, now at Banaras. Again the study of the drifting of sand and clay both by wind and water is most important for India, and a study of Bagnold's published work makes it clear that no foreign-made apparatus is needed for it.

If I had to advise a young physicist or chemist my advice would be as follows. Try to get into an Australian laboratory. Australia, though not a poor country, contains few rich men, and manual work is regarded as honourable. You are more likely to have to make your own apparatus than in U. S. A., and many of the problems which are being intensively studied there, particularly those of the chemistry and physics of soils and of water conservation, are not too far from those which matter in India.

Do not be too keen on the U. S. A. I have never had a pupil who went there for a doctorate, and plenty of Americans got doctorates under my supervision at Cambridge, and in my department in London. Of course if you can get into one of the great research departments, you are lucky. But there are plenty of second rate ones.

One of the things which has surprised me most in India is the poverty of its cultural contacts with Japan. Those which exist are largely in the field of Buddhist scholarship. And yet Japan is beyond doubt the leader of scientific research in Asia. There are two fields of biology in which Japanese workers are outstanding. One is the study of bacteria and other agents of disease. The other is genetics. At the moment I think the United States leads the world in genetics. But I consider that more good genetical research is being done in Japan than in any one of the European countries, such as England or France.

One can live cheaply in Japan, and although Japanese culture is very peculiar, there are two features of Indian culture which are echoed there. One is personal cleanliness. The

Japanese are, I think, a good deal cleaner than most Europeans. Another is vegetarianism. This is not normal, but there are enough Buddhists who take non-violence seriously to make vegetarian meals easily available in some cities at least.

I believe that Indian graduate students would be welcomed in many Japanese universities and other institutions. A lot of effort is being devoted to perpetuate the memory of Netaji Subhas Bose. Had he succeeded in his aims the bonds between India and Japan would certainly have been strong—some may think too strong. They are too weak now. I could wish that Netaji's admirers would establish a few scholarships for Indians to study in Japan. The Japanese language is difficult, but all Japanese scientists speak and write some English, so it would be possible to start research without mastering Japanese.

The Japanese imitated not merely European science, but European militarism. They are still suffering profoundly from the defect. I believe that Indians, and perhaps Indians alone, can give them the help and consolation which they need.

If I ask an Indian biologist in what country the yield of milk per cow is highest, he is quite likely to guess right, namely the Netherlands. There is some dispute whether Denmark or Israel* holds the second place in the world, but no doubt at all that the cows of Israel have a vastly higher milk yield than those of any other Asian country. And this is so although much of Israel is extremely dry, and the summer in Negev is as hot as in many parts of India. I do not hesitate to say that Indians who want to improve the milk yield of our cattle can learn more from Israel than from any other country.

And this is not an isolated fact. There are only about two million people in Israel, but its output of scientific research is comparable with that of some European states with ten times as many inhabitants. I know little of Israel's non-biological work. But its human, animal, and plant biology is first rate. In particular the Israeli government has to deal with immigrants

* Since this was written, Israel has probably overtaken the Netherlands.

from poor Asian countries such as Yemen and Iraq, and not merely to eradicate a number of tropical diseases but to bring the immigrants, in one generation, to a high level of hygiene. Indians have a lot to learn from such work. Israeli agriculture is based on an intensive scientific study of a rather small number of crops, many of which, such as oranges and the castor oil plant, are grown in India. The collective farms, called Kibbuzim, on which this knowledge is applied, are a good deal nearer to Indian ideals of socialism than to Russian ideals.

Language is of course a difficulty, but English is very widely spoken. And the fear of religious intolerance is out of date. As a minority the Jews could only preserve their identity by insistence on various rituals, for the same reason that Hindus did so as a defence against Muslim and Christian conquerors. Their ancient ritual had some repulsive features, including animal sacrifice. These are being rapidly jettisoned, as animal sacrifice has been in most of India not merely without harm to Hinduism but to its benefit. Moreover the philosophers who have come nearest to Sankara Acharya outside India have been two Jews, Musa ben Maimon and Benedict Baruch de Spinoza. An advaita Hindu might find himself more at home spiritually in Israel than anywhere else on earth. I hope that a few young Indian scientists will try.

The Soviet Union is another possibility. It is certainly leading the world in some branches of physics, chemistry, and biology. I would particularly recommend Indian biologists to go there to study natural populations of plants and animals, and geological prospecting. India urgently needs a survey of its natural resources like those which the U.S.S.R. has undertaken. The language is difficult, but a knowledge of Sanskrit should be of great help. And unless a number of Indian scientists not merely learn Russian, but something of the Soviet attitude to science, they may find themselves as isolated from important developments in the future as they would be to day if they had refused to learn English.

I have no time to write of the other European states, though many of them, and particularly France and Sweden, lead the world in some branches of science. I want to suggest Brazil as a place of study. Brazil has a range of climates much like that of India, though with a relatively larger humid area. It is the only state in the world which contains more species of flowering plants than India. Although the level of its universities is not uniformly high, it has produced some very fine workers in tropical botany, zoology, agriculture, and hygiene. There is very great economic inequality, as in India, but remarkably little colour prejudice.

I am not going to advise any particular student, still less to put them in touch with foreign scientists. If they are really interested in their subjects, they will know better than I do where work is being done on the lines which interest them. If they do not, let them get the habit of looking through Journals such as Nature, Experientia, Science, die Naturwissenschaften, and, if they can get it, Sowjetwissenschaft. Above all, I ask them to believe that the choice of where to go is very important. It may make the difference between a life of routine teaching and one which will help India to take her proper place among the nations.

POLDERS FOR INDIA

An item in the Second Five-year Plan which has not yet received much publicity is the project for reclamation of saline soils in the area of Bhal, on the coast of Saurashtra in Gujerat. The Government of the Netherlands is helping us by paying for the construction of a "pilot polder" of about ten square miles, or, as we must now learn to put it, twentysix square kilometres. Readers may well ask "What is a polder". This is a Dutch word meaning an area of land whose level is below high tide mark, and from which the sea, and river water, are kept out by dams. A large part of the Netherlands consists of polders, and they include some of the most fertile lands in the world. The old polders are all above the level of low tides. The sea is kept out by great dykes. Dyke is the Dutch word dijk for a bund or dam. Sluices in these dykes are opened when the tide has fallen far enough, and shut when it rises again. So the level of the fresh water in the polders is somewhere above the level of the sea at low tides, but well below high tide level. It is also well below the level of the rivers, mostly distributaries of the Rhine, which flow through the country. The new polders, from which water is pumped mechanically, are at still lower levels.

The old Polder system owes much to a very great man, Stevin, who was Quartermaster-General to the Provinces which revolted against the Spanish four hundred years ago. He organized a system of defence by flooding. The Spaniards were very competent soldiers, but they were even worse off in a flood than modern soldiers, because they wore armour. Stevin also founded the science of statics, and invented decimals.

A new era opened with the use of windmills for pumping water. They were first used in the seventeenth century, that is to say about three hundred years ago. Windmills were already used for grinding corn, but now they were built on a huge scale, and so became the most conspicuous features of some flat districts of the Netherlands. Engineers were brought over from the Netherlands to plan the drainage of the fens of the eastern England, and to make several English zamindar families, such as the Russells, extremely rich.

However windmills and the pumps worked by them were not very efficient. Much land was reclaimed in the seventeenth century, but little more in the eighteenth. In the nineteenth century steam engines came into use, and pumps were for the first time scientifically designed. Many more polders, well below sea level, were reclaimed. In the twentieth century it became clear that much greater conquests were possible, but only by planning on a national scale, which involved enormous expenditure long before any increase in the national income resulted.

Shortly before the second world war (I object to the capital W's which are frequently used in printing the name of this evil) the Netherlands Government completed a great dam across the mouth of what had been an inlet of the sea, the Zuyder Zee. This dam is, in my considered opinion, the most impressive of all human constructions, and I have seen the pyramids and Manhattan. I do not think it is the most beautiful of man's works, but my wife does so, perhaps influenced by the great flocks of wild ducks which live on it and behind it. She is also perhaps influenced by the knowledge that the world's most beautiful buildings, such as the Taj Mahal and many of the cathedrals of Europe, were built by workers often torn away from their families and very badly paid and housed, and financed by taxes wrung from starving cultivators. A broad road runs along the crest of this dam. In the middle the road stretches out of sight before and behind one. On one side the sea breaks on a slope of great stones. On the other side a fresh water lake fed by the Rhine extends as far as one can see. At each end of the dam a great system of sluices lets out the fresh water at low tide. One system is called after Stevin, the other after the great Dutch physicist Lorentz, who is responsible for much of the mathematical foundation of the theory of relativity.

After the dam was completed several years elapsed before the great lake behind it became completely fresh. Meanwhile the first polder behind it was being constructed, protected by its own dams, less solid than the main one, but still very tough structures. One polder was just completed before the Germans invaded the Netherlands in 1940, and one of their last actions as they left the country was to flood it again, destroying not only the crops, but millions of fruit trees. Since the war another great polder has been reclaimed. Its soil was about 6 metres below the low tide mark, and it is now a fertile land with well planned towns, and trees rapidly growing. A still larger area should be ready for occupation about 1960 or earlier, with a city called Lelystaat, after Lely who was the principal planner of the reclamation. By 1980 most of the former Zuyder Zee will be cultivated, but broad channels are being left between the polders, both to carry away flood water without a disastrous rise in water level, and to allow large ships to reach Amsterdam and other ports which are now in the interior of the country. These very low polders would be drowned in a few weeks if the water were not pumped out of them continuously. At present this is done by thermal power. But as atomic energy becomes available it may be possible to make polders at much greater depths than at present, and, among other things, to drain almost the whole of the Zuyder Zee.

A few years ago a great storm coincident with a high tide carried the sea over some of the older dykes surrounding islands in southern Holland, and drowned over two thousand people. The Netherlands Government is now constructing a giant dam which will protect these islands far better than was possible in the old days before huge blocks of rock could be transported for hundreds of miles to make it.

The experience gained in these great works will be used at Bhal. The area which could profit most from the experience of the Netherlands would probably be the Sunderbans of Bengal. But unfortunately most of these are now part of Pakistan, and cooperation is not at present possible. It is hoped to reclaim over two hundred square miles of salt marshes at Bhal. I presume that this will be mainly by the construction of old-style polders, not requiring much power for pumping. However as atomic energy is developed in India more ambitious schemes may be possible.

My object in writing this article is to interest Indian biologists in the changes which will occur. As the water behind the dykes gradually gets fresh, the marine animals will die. There will be a stage when fish, worms, and so on, adopted to brackish water, will predominate, and finally fresh water fish and plants will take over. This transition has of course been thoroughly studied in the Netherlands. It will be worth studying in India, and fortunately the Bombay Natural History Society is not too far away to do so. This study will of course be of economic value. It may be possible to speed up the conversion of salt marsh into agricultural land by sowing seeds of the right plant species. In the Netherlands this has proved to be the case, but of course Dutch experience will be of little use in India. If a good deal of fresh water is left behind the main dyke it should be possible to stock it with the most valuable species of fresh water fish. It may be possible to plant coconut trees, which appear to like a moderate amount of salt in the soil, long before other trees will grow well. The whole biological problem is intensely interesting, and I hope that it will be tackled thoroughly.

In any case it is heartening to read of India's conquests, not from other men, but from the deserts and the ocean.

THE REPAIR OF THE BHAKRA DAM TUNNEL

On September 2nd 1959 Hafiz Muhammad Ibrahim, the Irrigation and Power Minister, stated that expert naval divers would have to go down 250 feet below the water surface to close the right diversion tunnel of the Bhakra dam before any machinery can be salvaged. Or so I understand from press reports. The standard of reporting of parliamentary proceedings is incomparably higher than that of scientific lectures, but in such a technical matter it may possibly be inaccurate.

I know nothing about the details of the accident, nor exactly what the divers will have to do. But I do know about the divers' physiological and psychological difficulties. It is probable that I am the only person in India who has worked for many hours at pressures corresponding to over 250 feet of water. And I do not think many Indians have even the moderate experience of cave diving which I possess. Unfortunately I am 66 years old, and it would be silly for me to volunteer to do the job.

I do not know whether the divers who are to close the tunnel will wear self-contained dresses, or whether air will be sent down to them from the surface through a tube. If they can close the entrance without going into a tunnel, I think they should use whichever type of apparatus they are most accustomed to. But if they have to go some way into a tunnel, with an air tube and a telephone line trailing behind them, there is a good chance that one or other may get hooked round some projection. A diver in a self-contained dress, carrying his own supply of compressed air, would be well advised to remain in touch with the surface by telephone ; but a thin wire, which he could cut if it got entangled, would be sufficient.

Let us see what are the main dangers which beset any diver at this depth, apart from special dangers which occur if he has to enter a tunnel. If he were given pure oxygen to breathe, which would be safe and economical if he were going down to a depth of less than thirty feet, he would lose consciousness, with violent convulsions, in five minutes or less. I assume that the naval authorities concerned will not make this criminal error. If he is given air to breathe, he will begin to feel a little abnormal at 200 feet, and decidedly so at 250 feet. Fortunately 250 feet of warm fresh water only produce about as much pressure as 240 of cold sea water. And every foot counts. The queer feelings are due to intoxication by nitrogen, which is far from being a "physiologically inert gas" as stated in text-books of chemistry and physiology. At 300 feet some people have abnormal sensations. "My fingers feel like bananas", is a typical note. I do not have such feelings, but strange words come into my mind, and if I did not exercise self-control I might suppose that they were spoken by supernatural beings.

Much more serious is the failure of performance. When I was working on this question we tested ourselves and would-be divers in compressed air before we tried anything out under water. Among other things we tested the capacity of people to drop steel balls into holes, and to do four-figure multiplications. Not only did people break down on tests of manual skill, but they broke down morally and cheated. My wife was the only person out of a number tested who could do arithmetic normally at 250 feet, and even she certainly showed signs of mental upset. Very often people lost their tempers or began playing childish practical jokes. I could seldom remember to do all of a series of tasks, for example administering a test to another person, taking samples of air, reading thermometers, and so on. There are great differences in individual susceptibility, as there are in susceptibility to alcohol. So the first thing to do is to test the divers whom it is intended to use, and pick out those who are least upset by nitrogen.

It is possible however to avoid this danger by using a mixture of oxygen and some other gas. Only two gases need be considered, helium and hydrogen. If a mixture of oxygen with either of these gases is breathed, the symptoms which I have described, due to breathing air, disappear at once. However these mixtures are not without danger, and have killed at least one man. A mixture of about 97 volumes of hydrogen with three of oxygen is quite safe to breathe at 250 feet, and is not liable to explode. But it will not support life at the surface, and the process of switching over to this mixture from air, and back again, must be practised with very great care.

I consider that if the work is to start in three weeks, as is stated in the press, it is very dangerous to attempt to use such mixtures, unless the Indian Navy has already done so. When I use the phrase "very dangerous" I mean that E. M. Case and I, who were the first to breathe hydrogen-air and hydrogen-oxygen mixtures at high pressures, were none the worse. The third, a Swedish engineer called Zetterstrom, was killed through a mechanical failure.

The immediate effect of the nitrogen in air, when breathed at high pressure, is to cause one to make silly mistakes which may cost one's life. The other effects are equally serious. All the time that one is breathing air at high pressure nitrogen is dissolving in ones blood and passing from it into other tissues. When one comes up, bubbles of nitrogen may form in any of a number of tissues. The commonest place is probably in the small blood vessels of the skin, where they merely cause itching. The next commonest is the joints, where they cause temporary, and in my experience, not very severe pain, known as bends. If they are formed in the nervous system this is permanently damaged, as I know to my cost.

The way to avoid these bubbles is, first, to go down quick.

The descent to 250 feet should not take over two minutes. A competent but not very expert diver like myself can easily do it in that time. Perhaps ten or twelve men in all the world could do it in one minute. The moment his work is done, the diver should ascend to about 110 feet. If he goes higher, he is in danger of bubble formation ; if lower, he continues to absorb nitrogen which he will have to get rid of later. After this he gradually ascends to the surface, stopping every ten or twenty feet. Time tables for such ascents were first worked out by my father about 1908, but have of course been somewhat modified. He did not calculate time tables at greater depths than 200 feet. But the time for the various stages of ascent after only 15 minutes spent in descent and on the bottom at 250 feet would be about 90 minutes.

Dives to 300 feet and more were made possible by the Sir Robert Davis' invention of the submerged decompression chamber. This is a steel chamber let down by a cable, with a hole in the bottom through which a diver enters ; and room for another man. This is lowered to a depth of 60 feet or more, and can then be hauled up to the surface, and the pressure in it lowered by steps. When it reaches that corresponding to 60 feet of sea water the diver begins breathing oxygen. In consequence nitrogen leaves his blood about four times as quickly as if he were breathing air. After a 15 minute dive to 250 feet decompression would only last for another 33 minutes, and after an hour's dive, only 172 minutes. I do not know whether the Indian Navy possesses such a chamber. If not, it would in my opinion be criminal folly to try to use it after only a fortnight's practice.

Now let me point out a very serious danger. Some American firms have a lot of helium to sell. They state, truly enough, that mental confusion at great depths disappears when the diver breathes a mixture of oxygen and helium instead of air. They do not, or at any rate did not, state that it increases the risk of bubble formation. It does. After breathing air at pressures corresponding to 300 feet on several occasions, and decompressing without harm on a certain time table, I repeated this after breathing a helium-oxygen mixture. Not only did I get bends, but the nerve supply from the area of the body on which I sit down was so far damaged that I am unhappy, after 19 years, on a hard chair without a cushion.

If the divers are going to have to enter dark tunnels it would be better to make a model of these tunnels, flood it with ten feet or so of water, and practise moving about in it. However good your light, you may not be able to see far if you stir up mud. My last dive of this type was in a submerged cave. I went down to the bottom of a pool about nine feet deep, then head first down a shaft for another nine feet or so, and thirdly along a horizontal passage much too narrow to allow me to turn. Finally I entered a large and very beautiful underwater hall, and crawled up a narrow crack to an air-filled part of the cave. The boys who had invited me down came behind me, so I got a good view, while they could see little because of the mud I kicked up. It may be that men or women with experience of this short are needed at Bhakra.

According to press reports the Minister stated that "expert divers would have to go 250 feet below the water surface." He did not state whether any such exist in India. Unless a diver has spent at least 24 hours at depths of 250 feet or over, even if he has spent a long time at 50 to 100 feet, he is not an expert. He can no more expect to work efficiently or even safely at 250 feet than a man who has practised sailing at Naini Tal can be expected to sail a boat to Minicoy with safety.

The Indian Naval diving school is at Cochin, where the opportunities for deep diving are small. I was invited to visit it earlier in the year, but as a programme intended to last over two days included under two hours at the diving school, but numerous visits to other establishments to which I could be of no value, and at least one public speech to a non-official body, I decided that my visit would be a waste of public money, and declined the invitation. I am of course at the disposal of the Navy if they want my advice. There are plenty of younger men with more recent experience in other countries, probably including Japan. I very much hope that someone with the necessary experience will be called in. If not I fear that there may be some more deaths at the Bhakra dam.

There has been a serious colliery explosion at Chinakuri in West Bengal, in which nearly 200 people were killed. Such explosions were common in the U.K. sixty years ago, but have been rendered extremely rare. The improvement has been due to three causes, scientific research, with some of which I was associated, regulations for safety, and education not only of engineers and mine inspectors, but of miners. It is idle to hope that safety will be achieved in Indian mines until the men working underground understand the sources of danger, and how to counteract them. And this improvement can only come as part of a general rise in educational level. Even that will not be sufficient unless the general education includes at least some elementary science.

An explosion is a burning which happens almost instantaneously through a large volume. In most cases the burning is the combination of oxygen atoms with other atoms. In a solid explosive such as gunpowder the oxygen is in potassium nitrate, from which it comes off very easily, and later combines with carbon and sulphur. In an explosive such as trinitrotoluene the oxygen and the carbon and hydrogen with which it unites are originally in the same molecule, but separated by nitrogen atoms. However in a colliery explosion things are different. The oxygen is in air, and what is burned is either a gas called methane, or coal dust. So to prevent explosions one should take two different kinds of precaution. First one should prevent the accumulation of gas or dust in sufficient amounts to cause an explosion. And secondly one should avoid anything which might start an explosion if gas or dust is present. In the same way if one has a gun or pistol in the house one should take two precautions. Firstly the gun should not be left loaded, and secondly it should never be pointed at a human being, even if one is sure that it is not loaded.

A gas or dust explosion is dangerous on account of the heat generated by the rapid burning. This can scorch a man's skin, but a greater danger arises from the rapid expansion of the air caused by the heat. This pushes everything in its path, as the explosion of the mixture of air and petrol vapour in the cylinder of a car engine pushes the piston. Both gas and dust explosions use up the oxygen of the air and generate a poisonous gas, carbon monoxide. Finally an explosion may start a fire. This seems to have happened at Chinakuri.

Methane, which is called firedamp in England, comes out of the coal in many mines, and in such mines "naked" flames such as candles are forbidden. Either electric lamps are used, or an oil lamp is used with a glass chimney and wire gauze screens where the air enters below the flame and leaves above it. A flame can no more get through such a screen than a mosquito can get through the gauze screen of a railway carriage. When I was a boy my father gave me what Gandhi would have called basic education in science. I first went down a mine at the age of about four, though I did not go down a coal mine till later. I remember being taken into an abandoned part of a mine where there was no ventilation, and gas had accumulated. Methane is lighter than air, and collects near the roof. We crawled along the floor to avoid it. Then my father told me to raise my safety lamp. It filled with blue flame and went out. If it had been as large as a railway compartment the explosion would have gathered so much force that it would have shattered the glass and ignited the gas round it. Then my father told me to stand up. As there was very little oxygen in the firedamp near the roof I soon fell down again. However I had learned some chemistry.

Mixtures of gas and air in suitable proportions are rather easily set alight. A match can do so. So can a spark from an electrical apparatus, or perhaps even from a nail in a man's boot. In England a very common cause of explosions was what is called a gob fire. When the coal has been taken out of a seam the props which support the roof are withdrawn and the roof comes down. The crack which may remain between the roof and floor is called the gob or goaf. If too much coal dust and fragments are left there, and there is a draught through the gob, this waste coal may heat up and finally smoulder at a red heat. Such a gob fire can set off a gas explosion. Gob fires can sometimes be detected by smell long before any smoke is visible, but chemical methods are much more reliable.

Dust explosions are not so easily started. A cloud of coal dust must be quite dense before it explodes. Such dense clouds can be produced by wagons loaded with coal, by coal cutting machinery, and otherwise. More usually, however, coal dust is stirred up by a small gas explosion, and then set alight. Dust explosions can be more violent than gas explosions. I once saw an experimental one which tossed pieces of boiler as large as carts for 600 yards or so ; and though the local newspaper was dissuaded from reporting this fact (for the English press is no more incorruptible than the Indian), an earthquake was reported six miles away.

Considerable care is taken in British collieries to prevent the accumulation of dust. Roads, as the tunnels between the shaft and the coal face are called, may be watered, limestone dust may be mixed with the coal dust, and so on. This is particularly necessary in mines where explosives are used. Although explosives used in collieries are tested for the absence of a flash, these tests are not quite infallible, and extra precautions are needed to prevent dust explosions. From the newspaper account of the Chinakuri explosion which I have seen, it looks as if the explosion of a small amount of gas might have started a much larger dust explosion. Enough gas to kill more than one or two men can only accumulate through very gross negligence. But a moderate amount may suddenly come out of the coal, and if it is accidentally ignited, will explode. However if proper precautions are taken, it will not start a dust explosion.

The explosion only lasts for a second or less, but is extremely hot. So exposed skin is scorched. But though the clothing may be charred, the skin below it is seldom much damaged. Unfortunately in India miners wear fewer clothes than in Britain, and are likely to be burned over larger areas. Death by carbon monoxide poisoning is one of the least painful deaths that one can imagine. After a brief period of confusion one loses consciousness. Mine rescue teams are equipped with breathing apparatus which give full protection against it. It has been proposed that all coalminers should carry such apparatus. But this proposal has been rejected, as the apparatus is cumbrous. I am glad to read that a rescue team saved several lives at Chinakuri. Mine rescue is one of the noblest of human occupations, combining the honour and risk of the soldier with complete non-violence. The British teams have a magnificent record of courage, even though in the last few years they have had little chance of showing it.

No doubt there will be an enquiry into the Chinakuri disaster. Trade unions can play a most important part in such enquiries provided their representatives have a good knowledge of the necessary science and technology. Too often they are lawyers who know no more of chemistry and physics than I know of law, and are more concerned to make the witnesses called by the owners contradict themselves than to arrive at the truth. In such an enquiry it is no doubt important to find out, if it is possible, who was responsible for the explosion. It is much more important to prevent such explosions in future. This can only be done if the problem is regarded as a scientific rather than a legal question. But whatever precautions are taken I do not believe that Indian collieries will attain the high safety standards reached in Britain until the miners are sufficiently educated to understand not only what orders are given to ensure safety, but why they are given.

DEEP MINES

A number of miners have been buried in a very deep mine in Nova Scotia, a province of eastern Canada, and some have been rescued after more than a week. Press reports do not agree, but according to some of them the mine is a coal mine and just over four thousand metres deep. This is a surprising but not impossible depth. In the days when I followed such matters the world's deepest mine was a Bolivian tin mine about 3000 metres in depth. I have never been down more than a mile, which is about 1600 metres.

However even at this moderate depth some strange things were to be noticed. The shaft only went down vertically for 800 metres. The rest of my journey to the bottom was in a "tub", that is to say a truck on a very narrow gauge tramline going down a steep incline, attached to a wire cable. The ventilation at the bottom of this incline was not too good, and it was extremely hot by English standards. I think even Indians would have objected to hard work under such conditions. The English miners who were working there wore nothing but a diminutive dhoti tied on with tape, and a pair of boots. When they stopped work at "snapping time", for a small meal in the middle of the shift, they emptied the sweat out of their boots. The coal seam was less than a metre thick, so one had to wield a pick-axe lying on one's side, and although I was fairly robust, my efforts to do so, which only lasted for about ten minutes, greatly amused my companions.

There were three reasons why we were so hot. In the first place the temperatures of rocks increase steadily as one goes down. The gradients differ in different parts of the world, but one degree centigrade per forty metres is a representative figure. The heat is being produced by radioactivity in the earth's crust. It leaks out extremely slowly. How slowly may be judged from the fact that the gradient in northern England is far from uniform. The temperature rises rather slowly in the first 300 metres or so, and then much quicker. This is only the case in countries which were covered with ice during the last ice age. This lasted for over 20,000 years, and cooled down the outer kilometre or more of the earth's surface appreciably. The last ice sheet disappeared from England about 12,000 years ago, but heat seeps so slowly that the rocks have not yet warmed up completely.

A second reason for the heat is that the air which comes down the downcast shaft is warmed up by compression. The air at the bottom of a shaft a kilometre deep has to support the weight of a kilometre more of air than it did when at the surface. It is therefore squeezed into a smaller volume, and heats up like the air in a bicycle pump. Finally in many mines the rocks heat up through the slow oxidation of minerals such as iron pyrites.

In very deep mines some form of artificial cooling is necessary, if men are to work as hard as they can. The simplest method is to compress air at the surface. It gets very hot during the process, but soon cools down. If it is led to the working face in pipes it cools down on expansion. This is one reason why compressed air is a favourite source of power in mines. Another reason is that it is far less likely to produce sparks than is an electric current, though a rapid air flow can produce a static charge. Sparks are of course a real danger in coal mines where they may start an explosion.

In a cave or a shallow mine the silence is frightening. After a few minutes' sitting still one begins to hear the sound of one's own breathing and heart beat, unless, as is often the case, water is dripping somewhere within earshot. But, in coal mines at least, at depths below 500 metres there is no silence. One hears a constant series of little cracks. At 1500 metres these sounds arè much louder, rather like rifle bullets passing in a battle. This sound is due to the rocks cracking under pressure. Coal mines are excavated in fairly soft rock, and as the coal, which usually lies horizontally, is removed, the roof gradually sags down, so that the miners work in a space which may be called a triangular prism. However it is not only the roof which is under a strain. If one goes into a fairly deep coal mine after a strike which has lasted for a month or so, or which has been abandoned for a month or so after an explosion or a fire, one notices that not only has the roof fallen or at least become lower, but that the floors of the "roads", as the tunnels leading to the face are called, have bulged up. The rocks are solid, but under the pressure of the strata above them they flow almost like a very sticky liquid. However the flow is not steady, but in a series of little bursts. Apparently a big burst of this kind trapped the Canadian miners. The gold mines at Kolar in Mysore are deeper than any British coal mine, and no doubt tunnels close up if abandoned. But the rock is much harder than that of coal fields, and the gold bearing veins or lodes are nearly vertical. So the pressure effects must be less, and I do not know if the low levels are as noisy as a deep coal mine.

I have no doubt that our descendants will explore the depths of the earth as we are now exploring the upper air. But it will be as difficult for a man to go down 20 kilometres as to go up 200. I suspect that excavation will have to be done by apparatus under distant control, working in water or possibly some other liquid, under enormous pressure. This pressure will serve to balance the pressure of the rocks, and keep the shafts and roads from collapsing. The mere weight of a column of water will not be enough, for rocks are usually between two and three times as dense as water, and pressure will therefore have to be applied artificially to it. This is no more fantastic than the methods already employed in atomic power stations. The fact is that since the atomic industry is a new one, its workers are very much better protected than miners. For mining is a very old occupation. Moreover only a few mines in India are very deep, and the immediate task before the Indian mine-workers Unions should be to see that the standards of safety current in Britain are enforced here, rather than to think of the fairly remote future.

But it is a curious thought that the mining methods of a century hence are probably being tried out today at the bottom of the ocean. Apparatus is being lowered which will allow an observer on the surface to see a picture of the ocean-floor eight kilometres below him on a television screen, to pick up objects so seen, to make boreholes in the ocean floor, and so on. All these have to work at pressures of about a thousand times that of the atmosphere. Their design calls for considerable imagination. But if we cease to regard miners as expendable material, they will probably be replaced by apparatus of this kind.

I am a man of violence by temperament and training. My family, in the male line, can, I think, fairly be described as Kshattriyas. Before 1250 our history is fragmentary. From 1250 to 1750 we occupied a small fort commanding a pass leading from the hills to the plains of Scotland. Our main job was to stop the tribal peoples of the hills from raiding the cattle of the plainsmen ; but perhaps once in a generation we went south to resist an English invasion, and at least two of my direct ancestors were killed while doing so. Even when Scotland had been united to England by a royal marriage and the tribals had been pacified, the tradition persisted. When I was a child my father read to me Scott's "Tales of a Grandfather," which are legends of the warlike exploits of the Scottish nobility, and trained me in the practice of courage. He did not do so by taking me into battles, as his ancestors might have done, but by taking me into mines. I think he first took me underground when I was four years old. By the time I was about twenty, I was accompanying him in the exploration of a mine which had recently exploded, and where there was danger from poisonous gases, falls of roof, and explosions. So when in 1915, I was first under enemy shell fire, one of my first thoughts was "how my father would enjoy this."

I find many of the virtues and vices of the heroes of Indian epics quite intelligible and even sympathetic. The second word of the Gita, "dharmakshetre", gives an exact description of my feelings when I went to the trenches for the first time in 1915. I was well aware that I might die in these flat, featureless fields, and that a huge waste of human values was going on there.

Nevertheless I found the experience intensely enjoyable, which most of my comrades did not. I was supported, as it were, on a great wave of dharma. The European Kshattriya, or knightly virtues include a detestation of various kinds of meanness, and a hatred of violence against the defenceless. The European knightly vices include an addiction to gambling. I understand Yudhisthira's point of view. A Kshattriya should never feel secûre. His dharma implies that he must be prepared to risk his life, and lose it if necessary, at a moment's notice. He must therefore be prepared to risk his property. I confess that I have less sympathy with his staking his wife and his brothers.

In the war of 1914-1918 I was on several occasions pitted against individual enemies fighting with similar weapons, trench mortars or rifles with telescopic sights, each with a small team helping him. This was war as the great poets have sung it. I am lucky to have experienced it.

We have now to consider two facts. The Gita, which is an exhortation of Arjuna to violent conduct, was the favourite poem of Gandhi, the great exponent of non-violence. War has changed its character completely in my lifetime. Modern war has two principal forms. One form is characterised by the wholesale massacre of defenceless civilians with atomic bombs and other weapons. The other, which is going on in Algeria, Malaya, Kenya, Cyprus, and other regions, is characterised by the use of ambushes and individual murder by the less armed side, and the killing of prisoners and the enslavement of whole populations by the more strongly armed side.

Modern war does not evoke any of the Kshattriya virtues except courage. But yet these virtues are absolutely needed in modern life, as Gandhi saw. The contradiction is of course latent in Hindu mythology. Not only Rama and Krishna, but even Buddha, the great preacher of non-violence, were Kshattriyas. But Parasurama, the son of Jamadagni, another avatar of Vishnu, had devoted his life to the extermination of that caste. How then can we combine the Kshattriya virtues with non-violence ? Gandhi gave one answer to this question. There are other answers, quite compatible with Gandhi's answer, but in different spheres. Gandhi was always concerned in struggles between human groups. He did his best to eliminate violence and hatred from them.

There is another kind of struggle. I quote St. Paul's letter to the Ephesians, the translation from the Greek (from memory) being my own :

"For our struggle is not against blood and flesh, but against first principles, against powers, against the lokapalas of the kaliyuga, against the spiritual sources of evil in the heavens." I translate his word kosmokrator or world governor, as lokapala. The phrase translated as kaliyuga means literally "the darkness of this age." I think that the notion of the lokapalas had reached Western Asia from Buddhist sources in St. Paul's day.

Some of us struggle against the natural forces which in India are too often worshipped as minor deities, for example cholera and small-pox. My father was mainly concerned with such matters as the ventilation of factories and mines, which is important both in safeguarding health and preventing explosions. When he wished to investigate why men died after colliery explosions when they had received no physical injury, he first examined dead men and horses after underground explosions, convinced himself that they had died of carbon monoxide poisoning, and then proceeded to poison himself with this gas. That is to say he breathed a known amount of it until he had fallen over unconscious, and a colleague pulled him out of the gas chamber. In this way he found out how long it takes for a given amount of this gas to overcome a man. He also found that small birds are overcome much more quickly than men (and recover much more quickly). He was however averse to experiments on animals which were likely to cause them pain or fear (carbon monoxide poisoning causes neither). He preferred to work on himself or other human beings who were sufficiently interested in the work to ignore the pain or fear. His experiments on the effects of heat could perhaps be called *tapas*. He found that he could live in dry air at 300°F. At about this temperature his hair began to singe when he moved it.

But I do not think his motivation was that of an ascetic practising *tapas*. He achieved a state in which he was pretty indifferent to pain. However, his object was not to achieve this state but to achieve knowledge which could save other men's lives. His attitude was much more like that of a good soldier who will risk his life and endure wounds in order to gain victory, than that of an ascetic who deliberately undergoes pain. The soldier does not get himself wounded deliberately, and my father did not seek pain in his work, though he greeted a pain which would have made some people writhe or groan, with laughter. I think he would have agreed with the formulation that the *atman* or *buddhi* in him was laughing at the *ahamkara*.

I have tried to imitate him. I have drunk or breathed considerable amounts of various poisons, certainly more than half the fatal dose in some cases, and have done similar experiments on other human volunteers, including my wife. For this reason I feel a certain annoyance when I am excluded from a temple of Siva, who, according to a well-known legend, drank poison to save the other gods. If Siva exists, he may be more pleased by such an action than by the recitation of a lakh of *mantras*.

I believe that this non-violent approach to experimental biology is a fruitful one. I do not condemn those who do experiments on animals which involve their death, or even moderate suffering. But I have never done an experiment on an animal of a kind which I have not previously or subsequently done on myself; and I hope I never shall. I have dissected dead animals. But I have left instructions that my own body should be dissected by medical students. And if I die in India

I hope some future Indian doctors will have the unusual experience of dissecting a European.

One great advantage of working on oneself or a friend is that far greater accuracy is possible than is usual in experiments with animals. If an animal is in pain or fear, for example, its heart is likely to beat faster and its rate of breathing may also increase. This will make it impossible to measure the effect of a drug on its pulse rate or breathing with great accuracy. But when one has done a number of experiments on oneself, one can do them on animals with some confidence that the results will be as accurate as if they were done on men.

When we were in India in 1954 my wife and I did a number of experiments of this kind on three *koi* fish. When these fish are put in foul water containing little oxygen they swim up to the surface and breathe air. We teased our fish in various ways by altering the composition both of the gases dissolved in the water in which they swam and the air above it which they breathed. I don't say these fish never suffered at all. To judge from my own experience they may have had severe headaches for some minutes. But they were certainly not seriously injured, for all three of them are alive and well in London today.

I am not at all a saintly person. I have killed animals, and eat meat, though not very much. Since writing this, I have ceased to eat meat or fish. My attitude to animals is more like that of Yudhisthira. He had killed and eaten plenty of deer. But when he was asked to enter *Svarga* leaving the dog which had been his companion on his last pilgrimage to die on the mountain, he found, perhaps to his surprise, that this was something which, as a *Kshattriya*, he could not do. No more could I or my wife have given the *koi* fish which we had watched for two months to someone else to kill and eat.

I want to urge that this kind of attitude to animals should commend itself to Indian biologists. Unfortunately it is rather rare. I think that it should be the rule. But of all the Indian biologists whom I know the man who comes nearest to it is a Muslim, your great ornithologist, Mr. Salim Ali. He is prepared to admit that he has occasionally shot birds, but he greatly prefers studying them when alive.

Frankly I regard his attitude as a challenge to Hindu biologists. There is a very great opening for non-violent biological studies in India, and, what is important, they require no complicated apparatus. Let me give some examples of what could be done. Do your song birds sing their songs if they are brought up from the egg by human beings? Or do they have to learn their song as a human being learns a language? In Europe and North America we know that some birds must learn their song, while others produce it untaught, as some mythical Hindu characters were born with a knowledge of the Vedas. If they have to learn, some species learn from their fathers. Our English robin sings very little while helping his wife to keep the eggs warm and to feed the children which emerge from them. But when the children are just learning to fly he bursts into song again for a few weeks. This may be an expression of paternal pride, but it gives his sons the chance to learn from him. Other birds do not learn till they are nearly a year old, when they learn from other males. To bring up young birds till a year old requires an aviary where they can fly about, and a great deal of devotion. The latter is common in India, but it is commoner among illiterate people than among biologists.

If ever I settle down in India I hope to continue the study of the almost non-violent branch of biology called animal genetics. If, for example, I want to breed ducks, the conditions in many parts of India, including much of West Bengal, are ideal. One would need some wire netting to prevent unwanted matings, and perhaps a balance, a tape measure, and a chart of colours, but no other apparatus. One would of course need land with small tanks, a certain amount of food, but above all, assistants who would take the greatest care of the ducks. Such work would certainly yield many facts of biological interest, and probably increase the egg production of your ducks. Genetics is not, of course, completely non-violent. We breed a lot of flies in my laboratory, of a species which normally lives on sap from injured trees. If we let the surplus ones out in London they would starve to death. We therefore anaesthetize them and drown them in oil before they recover from the anaesthetic. I sympathise with, but do not share, the Hindu practice of non-violence to insects. They will die in any case, but they need not suffer. I am ashamed if I cause an insect suffering, but not if I kill it painlessly. It would be quite possible to practice insect genetics without offending the scruples even of a Jain. But it would mean liberating animals most of which would starve to death.

GANDHI was quite clear that men have a duty of non-violence to animals. And there is no reason why biological research in India should not be conducted on Gandhian principles. On the contrary, there is very good reason why much of it should be so conducted. If Indian physiologists were ashamed to do an experiment on an animal which they could do on themselves, Indian physiology would, in my opinion, be considerably more fruitful. The most effective method of mosquito control is not to kill mosquitoes, but to give them no opportunity of laying eggs. If you have too many cows, you should try to breed cows which will go on giving milk for more than a year after a calf is born, as some of our European breeds can. You will then have fewer cows, and more grass for each cow to eat. If your traction is largely mechanized in future you will want fewer male calves. My wife has a male fish who (as predicted before he was tested) has begotten only daughters. There does not seem to be any intrinsic impossibility in producing bulls who would do the same, though many lifetimes of human research may be needed before this is achieved.

Thousands of Indians die of snake bite every year. But the cobra is one of the most beautiful of animals, and I should be very sorry to have to kill one. It is just as possible to immunize the rural population of India against the poisonous snakes which live in their neighbourhood as to vaccinate them against smallpox. But the methods for doing so safely and on a large scale have not been worked out. This is a task for non-violent Indian biologists. Two or three of them might die of snake bite before the process was fully worked out. If so they would not have died in vain. At a later date it might be possible either to breed cobras whose poison did not kill men, or men who were not harmed by the bite of a cobra. Meanwhile I should like to meet even one Indian biologist who had immunized himself (or herself) against all snake poisons, and was prepared to answer a telephone call and remove an unwanted cobra or krait from a house without killing it.

Such ideas no doubt seem silly to many Europeans. If they seem silly to Hindus, this means that there is something badly wrong with modern Hinduism. In my opinion several things are badly wrong with it. In particular the love for all animals which is expressed in your scriptures and your art has been replaced by a series of formal prohibitions. Gandhi realised that if non-violence to human beings is to be effective, it requires both courage and intelligence. He had plenty of both. I have tried to show that courage and intelligence are needed if non-violence to animals is to be something positive, based in all cases on the love of men for animals, and in many, on the love of animals for men.

Politicians may not like this article. They may say that it calls for a diversion of effort from important to unimportant fields. I do not agree. In my experience kindness to human beings and to animals usually go together. Those who ignore suffering in animals find it easier to ignore human suffering, and conversely. I think that Indians who love animals are often perplexed because they do not see how to give practical effort to their love. I have made some suggestions, and venture to hope that some of them will be accepted. India has made many contributions to world culture. Perhaps the greatest is the ideal of non-violence. Europe's greatest contribution is the scientific method. If these can be married, their offspring may raise mankind to a new level.

SCIENCE AND FLOODS

Once more the monsoon of 1959 has brought disastrous floods; the worst being in Kashmir at the beginning, and now, near the end, in West Bengal. It is reasonable to ask what scientists can say about their cause and prevention. If one may give an epigrammatic answer, floods are a sign of immaturity both in landscapes and in governments.

The landscape of Kashmir is extremely immature. You cannot go far in the valley without seeing some of the peculiar hills called moraines. These are made of clay with large and small stones, and have been formed by glaciers. A glacier is a slowly moving river of ice which can carry down not only mud and gravel, but boulders as large as houses. These are deposited wherever the ice melts. The commonest kinds are lateral moraines at the edges of glaciers, and terminal moraines formed at their ends when the climate remains steady for some centuries, and the glaciers neither advance nor retreat, but deposit their loads in the same place for a long time. The beautiful meadow of Gulmarg, for example, is almost surrounded by terminal moraines. Now a glacier has nothing corresponding to floods. So when the glaciers of Kashmir began to melt twelve thousand years or so ago they left a landscape in which the valleys were not adapted to deal with a sudden rush of water. We have a few similarly immature areas in England, notably the Vale of York, where moraines laid down by ice hold up water which would drain away more quickly if valleys had been made through them by nature or by men.

The landscape of West Bengal is immature for other reasons. In the north the Himalayas are still rising, as is shown by the frequent earthquakes, and in the south the delta, to which the Ganga and other rivers such as Damodar contribute, is still growing at the expense of the sea. The southern slopes of the Himalayas are so steep that the rivers can carry big loads of gravel which they deposit in the plains. These not only ruin fields, but cause the rivers to seek new courses.

The most homicidal of all rivers is the Hwang Ho in north China. Its upper reaches run through the fine dusty soil called loess, which was blown to its present position by winds during the last ice age. This is being eroded, and laid down as mud in the plains below. The river bed gradually rises above its surroundings, and naturally changes its course from time to time, drowning lakhs of people. Indian rivers such as the Teesta do the same, but fortunately on a much smaller scale. The Po and its tributaries in northern Italy have the same tendency, but they have been controlled to a considerable extent, and Indian engineers would do well to study Italian methods of flood control. It appears that the dredging of several rivers in West Bengal, such as the Bhagirathi, has been seriously neglected.

If nature takes its course, these dangers will largely disappear in a few million years, or even a few lakhs of years. The Teesta and similar rivers will have brought down enough gravel to enable them to form relatively permanent valleys. The floor of the Valley of Kashmir will have been raised, and the gorge through which the Jhelam leaves it will have been deepened. The delta regions of Bengal will slope gently like the plains of Uttar Pradesh.

But human beings cannot wait. What can they do now? The first thing, no doubt, is to collect information and analyse it statistically. This does not appear to be done very adequately in India. In a leading daily newspaper of October 5, I read the following sentences about the floods in the Damodar valley, which raised the water level behind the Panchet dam. "Previous statistics show that the probability of heavy rain so as to raise the level to 433 feet is once in 50 years and to raise the level to 435 feet is once in a thousand years. Both the figures were crossed this time". If these figures were invented by an imaginative reporter he would be well-advised to take up science fiction ; if by a statistician he would be of more use to his country if he were carrying earth in a basket to make bunds.

If there had been continuous records of rainfall or stream flow in the Damodar Valley since the time of the battle of Kurukshetra, which is commonly thought to have been some what over three thousand years ago, we could make a rather uncertain prediction as to what was to be expected in the next thousand years, assuming that various conditions remain steady. In fact the longest series of rainfall records in the world is for Pavia in northern Italy, and goes back for only about two hundred and fifty years. I should be surprised if any rainfall records in the Damodar basin went back much beyond 1900. If they do they do not help us. A heavy shower may deposit ten inches of rain in a small area during a day. This may not cause serious floods. But four inches in a day over a large area will do so. We have not got enough data for any part of India to make predictions about the worst flood to be expected in a century, let alone a thousand years.

With some kinds of statistics we can make predictions about a sample of a thousand on the basis of a sample of a hundred. This is so, for example, for heights of adult men. It is true for annual rainfalls in some places, but not in others. But even if it were true for rainfalls over several centuries it would not be true over longer periods. To take the history of only the last two thousand years in Europe we know that winters were a good deal colder in the time of the Roman Empire than to-day. Armies crossed rivers on ice which are now seldom even lightly frozen. From about A. D. 500 to 1,000 the weather was warmer than now, and Greenland was colonised. Then came a colder spell of several centuries, and the last century and a half has been warmer. At the present time we are having unusual weather. The summer of 1959 is said to have been the warmest in England for two centuries.

This may be due to natural causes. And if so the general average of the weather may be changing. Or it may be due to the discharge of atomic bombs, whose full effects are not understood. Those who assert positively either that they have or have not affected the weather seem to me to be about equally unscientific. However, that may be, the weather in the next century may turn out to be very different from that in the last.

The Panchet and Maithon Dams, like many others, are supposed to serve a triple purpose, hydro-electric power supply, irrigation, and flood control. At the beginning of the monsoon they probably do so. The water level in the lakes above them has fallen fairly low, and there is plenty of room to receive large amounts of water if there is heavy rain in the catchment areas which drain into them. The Kashmir floods were at the start of the monsoon, and a few empty reservoirs would at least have alleviated them. But during the monsoon these dams filled up, and their sluices had to be opened to avoid a possible burst. The same dam cannot be fully efficient for water shortage and flood control. The level at which the water is kept is a matter of policy which should be decided scientifically on the basis of such statistics as exist and of weather forecasts. I do not know how it is decided. I do know that the decision made this year was disastrous.

There are other methods besides damming rivers and dredging them by which floods may be avoided. One is by planting more trees in the areas of heavy rainfall, and protecting those which exist from destruction by men or goats. Planting is particularly needed in Kashmir. Another is by proper siting of new towns. According to the same newspaper which I quoted earlier, at Durgapur "the whole area in the plant site is totally submerged". Quite enough of our old cities are built on sites which are easily flooded. To build a steel plant round which a great city will grow up on such a site is a piece of stupidity, whether stupidity of Ministers or of civil servants it is probably impossible to discover.

Floods are a more serious danger in India than in Western Europe, and Indian scientists and engineers will have to work out their own methods of preventing them. The Chinese are certainly tackling the matter in a very big way, but I do not know whether it is the most efficient possible way. And the Hwang Ho at least is decidedly unlike any Indian river. So I do not know if the Chinese can help us very much. I believe that Indian scientists can do more for their country and for the world by investigating the causes of Indian floods and the methods of preventing them than by much of the research which they are actually doing.

DARWIN IN INDIAN PERSPECTIVE

It is probably too early to assess Darwin's significance for human culture. It is however much easier to do so if one has the stereoscopic view afforded by a measure of intimacy with more than one of the main cultures of our planet. I could not have written this article before I became an Indian. To Europeans and Americans it inevitably seems that Darwin's greatest achievement has been to convince educated men and women that biological evolution is a fact, that living plant and animal species are all descended from ancestral species very unlike themselves, and in particular that men are descended from animals. This was an important event in the intellectual life of Europe, because Christian theologians had drawn a sharp distinction between men and other living beings. In view of Jesus' remarks about sheep, sparrows, and lilies, this sharp distinction may well be a perversion of the essence of Christianity. St. Francis seems to have thought so.

But in India and China this distinction has not been made, and according to Hindu, Buddhist, and Jaina ethics, animals have rights and duties. My wife has stated categorically that Darwin converted Europe to Hinduism. This is, I think, an exaggeration, but is nearer to the truth than it sounds. Hinduism is not a religion as this term is understood by the adherents of proselytizing religious beliefs. It is an attitude to the universe compatible with a variety of religious and philosophical beliefs.

Such attitudes are best shown in imaginative writing and art. In one of the two great epics of ancient India, the Ramayana, the divine hero, Ram, is aided to regain his wife, Sita, who has been abducted by the ogre Ravan, by an army of monkeys and bears, acting on information received from vultures. In a relic at Mahabalipuram depicting scenes from the life of Krishna, which is one of the masterpieces of mediaeval Indian art, the whole background consists of cows' heads. For every Hindu the background of human experience is alive. Of course he does not live up to his attitudes and beliefs. Nor do Christians. If even fifty per cent of Christians forgave their debtors, from the boss who owes a week's wages to the farmer who has mortgaged his means of livelihood, the economic fabric of Christian civilization would collapse in eight hours. Similarly many, perhaps most, Indians, are cruel to animals ; but kindness to animals, including vegetarianism, is commoner in India than forgiveness of debtors in Christendom.

If Darwin had died young, Wallace would presumably have promulgated the theory of evolution by natural selection when he did, and it would probably have been accepted, though as Wallace's arguments covered a smaller field than Darwin's, the acceptance might have been slower. And as Wallace left loopholes open for supernatural intervention, which Darwin did not the immediate effect on western thought might have been less.

In my opinion however Darwin's most original contributions to biology are not the theory of evolution but his great series of books on experimental botany published in the latter part of his life. They are concerned with those aspects of plant life which are most like animal and human life. Two are devoted to climbing plants and insectivorous plants respectively and three to sexuality in plants, but particularly those aspects which are most human, such as the evil effects of incest (the theme of "Oedipus" and "The Cenci") and the strange devices by which its most extreme form, self-fertilization, is avoided. The facts discovered are momentous. Among their applications are the discovery of plant hormones and the invention of the weed killers which resemble them chemically, and the systematic outbreeding of maize, of whose importance for the agriculture of the U.S.A. I need not write.

But what was the attitude which led to these discoveries ? To answer this question we must not only read Darwin's books, but his autobiography, and the memoir by his son Francis. Perhaps the most enlightening passage is Francis' account of what his father called "a fool's experiment". Francis was ordered to play the bassoon to some seedlings. In fact this did not influence their growth, as vibration of the table had done. However other fool's experiments came off. Perhaps Darwin's classical fool's experiment was to cut a number of scalene triangles of paper, to leave them on his lawn, and find that the earthworms which used some of them to plug their holes generally chose the most acute angle to drag as far as possible down the hole. Darwin did not draw a sharp line between earthworms and the old gentlemen who had failed to interest him in mathematics at Cambridge.

Here are some passages from Francis' account of his father's attitude to plants ? "I used to like to hear him admire the beauty of a flower ; it was a kind of gratitude to the flower itself, and a personal love for its delicate form and colour. I seem to remember him gently touching a flower he delighted in ; it was the same simple admiration that a child might have. He could not help personifying natural things. This feeling came out in abuse as well as praise e.g. of someseedlings— "The little beggars are doing just what I don't want them to". His emotional attitude to animals was one of profound aesthetic admiration. One of his favorite words was "wonderful". Here is a typical passage concerning the second stage larvae of barnacles. "They have six pairs of beautifully constructed natatory legs, a pair of magnificent compound eyes and extremely complex antennae ; but they have a closed and imperfect mouth, and cannot feed".

In India we expect and find this attitude in saints. But it does not issue, as in Darwin's case, in increased knowledge.

The usual effect is a flood of sympathy with animal and human suffering which affects a few thousand people and then degenerates into a new set of ritual prohibitions. It led Darwin to observe the objects of his love with great accuracy. Darwin, then, from the Hindu angle, had some at least of the attributes of a saint.

The movement of art in the last century has been away from Darwin, not only in Europe and North America, but in other countries strongly influenced by them. We are less interested in the details of natural objects than were our grandparents. I expect this is a mere symptom of the senility of "western" culture. I do not expect any cultural renaissance until scientific research is an honoured and powerful occupation. When scientists, and particularly biologists, can influence taste, I think the program for visual art will be "Back to Albrecht Diirer."

Even before this, I venture to hope that Darwinism may be starting to affect our logic. We do not always realise how much of our ordinary thought is due to Aristotle's difficulties in classifying animals, and to the methods of classifying them which he finally adopted. The greatest Christian theologians, including St. Thomas Aquinas and Calvin, adopted Aristotle's logic, though not his metaphysics.

Aristotle's logic is based on similarities. Darwin in the last chapter of the Origin of Species, foreshadowed a logic based on differences. I quote two sentences only. "Systematists will have only to decide (not that this will be easy) whether any form be sufficiently constant and distinct from other forms, to be capable of definition, and if definable whether the difference be sufficiently important to deserve a specific name". "Hence, without rejecting the consideration of the present existence of intermediate gradations between any two forms, we shall be led to weigh more carefully and to value higher the actual amount of difference between them."

We can now see that this last sentence was the programme for a whole branch of statistics. Today we can answer two questions which could not be answered in Darwin's time. First, "Does population A of animals, plants, or men differ significantly from population B, or could the observed difference be due to randon sampling from the same larger population ?" Second "Does population C differ more or less from population A than from population B ?". What is perhaps of most significance is that the statistical methods devised by Gossett, Mahalanobis, and others to answer these questions as to biological data are now becoming important in physics, geology, and other sciences. Many scientists think that all the sciences will become statistical. If so, Darwin will be recognized as a pioneer in this development.

In the field of ethics Darwinism has probably so far been responsible for more harm than good, as a result of gross misrepresentation, for which however he himself bears some responsibility. Darwin was led to the theory of natural selection by reading Malthus. But natural selection operates in a population so fortunate that there is room for every member of it. For example, the human population of North America has been increasing steadily since 1700 A.D. or earlier, and for two centuries land was available on the open frontier. However some of the inhabitants in 1700 left many more descendants than others. There was selection for fertility, resistance to disease, and other characters. The population of France has been nearly stationary for sixty years, but not through famine or pestilence. However natural selection occurs within it.

Again Darwin naturally concentrated on obviously adaptive characters, such as teeth, horns, and the like, which are of value in the struggle between predator and prey, or between competing males. Their value is more obvious than, say, that of the production of granulocytes which are needed to resist many infections. However natural selection is far more efficient in eliminating human babies without granulocytes (a recessive character) all of whom die in their first year, than wild mammals whose black color renders them conspicuous to enemies.

In consequence, although he repeatedly pointed out the importance of physiological adaptation, he certainly left the impression that the struggle for life was analogous to war and economic competition in the human species. And Darwinism was used to justify such activities.

The persons who did so were presumably aware of Jesus' statement "Blessed are the meek, for they shall inherit the earth". They were not aware that this statement is substantially true, both in human and evolutionary history. Centripetal selection is normal. That is to say extremes leave fewer offspring than animals or plants near the average. This appears to be so even if selection is occurring fairly rapidly. Giant species also appear to be much less likely than those of moderate size to leave descendants.

It is a commonplace of human history that ruling classes die out. They may be massacred, but infertility seems a commoner fate. Fisher has argued cogently that the practice of marrying heiresses (who must be members of small families) has concentrated genes for infertility among ruling classes. Kinsey reported sexual behaviour making for low fertility among the richer and better educated Americans. Whatever the reasons economic success is usually correlated with biological failure.

The American negroes offer a conspicuous example of the truth of Jesus' statement. An appreciable fraction of West Africans were sufficiently meek to be capable of living as slaves, which members of prouder races were not. In consequence their descendants are now in a majority in several regions of the American continent and its neighbouring islands.

If this fact of the survival of the meek is ever realised, the consequences may be surprising. I cannot myself foresee them. For the meek do not want to inherit the earth. I have been studying the theory of evolution fairly intensively for some forty years, and I am convinced that, given the facts of genetics, natural selection can be relied on to produce unexpected results.

To sum up, Darwin was too great a man to assess just yet. In each succeedtng generation new aspects of his work appear important. Those which I have emphasized may appear less important fifty years hence. But perhaps the perspective of Darwin from an Indian point of view may be a corrective to the "western" and Soviet perspectives.

IN DEFENCE OF SCIENCE

I have just read the reports of the Speeches of the Prime Minister and of Professor S. K. Mitra to the National Institute at Delhi on the last day of 1960. Unfortunately I did not hear them, as I took the view that, having three broken bones at the age of sixty-eight, I should do well not to attend. This is perhaps an example of the "softness" which Mr. Nehru deplores.

Has Science reached a boundary ?

Let us begin with Professor Mitra. He is reported to have said "The scientist has come to a stage beyond which he cannot proceed. This holds true both in the case of the physical world and that of the biological world. Boundaries of knowledge have been reached which cannot be crossed". This is a very fair statement of a view with which I totally disagree, though I have hold something like it in the past. Professor Mitra would, I suppose, justify his view somewhat like this. Suppose we wish to determine just where a small particle is, and how quickly it is moving ; this is impossible, for we cannot observe it without altering its motion, and if the particle is light enough, the alteration is considerable. This is true. But have we any right to ask exactly where a particle is, and how quickly it is moving ? According to the generally accepted principles of science, we have no right to ask a question which cannot be answered. We must only ask answerable questions. For example we must not ask what is the colour of an atom, or indeed of anything smaller than a wave-length of light. We can ask various questions about it, however, which cannot be answered if asked about ordinary pieces of matter.

There is as yet no general agreement about what sort of questions are answerable about small particles, such as electrons. But it looks as if some of the questions could be answered exactly, whereas according to school physics they cannot be. Let us take a simple example. If I am asked how much Indian coinage I have in my pocket, I might give an answer in tolas or milligrams. But I should know that it was not accurate. If I say 5307 milligrams I merely mean that the weight is nearer to 5307 than to 5306 or 5308. But if I say 136 naye paise I mean exactly that. Now it seems that bodies can only have a whole number of units of spin, whereas in ordinary physics we assume that the spin can vary continuously. As the number of spin units in the wheel of a moving bicycle is a figure with about 35 digits the assumption of continuous variation is good enough in everyday life.

To put things in another way, material objects have properties which physicists call mass, or inertia, roughly corresponding to *tamas*, and energy, roughly corresponding to *rajas*. They also have organization. For man-size bodies we recognize organization by ethical and aesthetic criteria. We say that a good man has his mind more organized than a bad one, for example his passions under control. We say that a woman with a symmetrical face is more beautiful than one with an asymmetrical face, and so on. In some cases at least this organization agrees with the philosophical notion of *sattva*. When we get to objects as small as molecules we can give an account of this organization in terms of physics. This is the greatest achievment of physics in the last fifty years, generally called quantum mechanics. Even the smallest particles have a quality a good deal more like *sattva* than seemed possible when this century began.

We can already describe this quality fairly exactly for some light atoms and molecules. But it is described in a peculiar mathematical symbolism which is very far from being finalized. More accurately there are several different sets of symbols which describe it about equally well. We say that a molecule can only be in one of a set of "states", which determine its behaviour, for example what is the size and shape of the space from which it will exclude other molecules, what kinds of light it will absorb or emit, and so on. And we can calculate a lot about these "states", In each year we are learning more and more about such matters. I see no sign of boundaries of knowledge which cannot be crossed. There are certainly questions which cannot be answered. But I agree with the view that they are nonsenscial questions like "How loud is a round square ?" or "Can a man with seventeen legs jump as high as his own head ?" So I don't share Professor Mitra's despondency. We can't answer some questions which were thought to be answerable when Professor Mitra and I went to school. But we can answer others which, in those ancient days, no one had asked.

Still less do I see any sign of impassable boundaries in biology. Certainly there are unanswerable questions. It is quite certain that mind cannot be explained as a property of a system of particles each with a definite position and velocity at a given instant. I think it most unlikely that even the simplest kind of life, let alone that of a tree, an insect, or a bird, can be so explained. But as the physicists are now finding that it is illegitimate to think of atoms on other particles in this way, this does not mean that there is an impassable boundary between matter and life, or between life and mind.

The Marxist Darsana

A good many scientists in Western Europe and America agree with Professor Mitra, but very few do so in the Soviet Union. It is a tenet of the Marxist philosophy that matter exists, but that it unites opposite qualities. I think that "the unity of oppósities" may be a better translation than "illusion" of the sanskrit word "maya". According to Marxism, especially as developed by Lenin, this unity of opposites is the ground for development of material systems, and also of human accounts of them. For example evolution, and even the very modest forms of evolution which we call plant breeding and animal breeding, would be impossible if offspring did not resemble their parents at all, or if they resembled them completely. The reproduction of plants or animals unites heredity and its opposite, variation.

However satisfying an account of a material system we can give, it will always. according to Marxism, be found not merely to be inaccurate but self-contradictory when we know more. If this is true there are no impassable barriers. We can never reach complete truth, and can always change our ways of thinking so as to resolve any particular contradiction, and thus increase our capacity for predicting and controlling the behaviour of matter.

The dangers of leisure

The Prime Minister was afraid that human beings "might begin decaying as the result of leisure" "due to the application of science". It seems to me that the people of India to-day are suffering severely from too much leisure. Millions are unemployed. Perhaps half the population is under-employed. But thirty years hence Indians may be faced with leisure combined with plenty rather than want. This is common in the United States and a great many people waste their leisure very completely. They sit watching television or listening to gramophone records, and take very little exercise. Once they have made enough money to buy an annuity they retire into a rather elaborate private hell. Such a situation does not arise for people who feel themselves dedicated, and go on working till they fall dead. But it is only fair to the United States to add that an increasing number of people there spend their leisure in constructive work. There is a big market for high-class tools and small engines, suitable for use in the home. And many retired people find satisfaction in making their own furniture, vessels, or even telescopes. This is a most hopeful sign, and may point the way to a future decentralization of industry of which Gandhi would have thoroughly approved.

There are, however, other ways of avoiding excessive leisure. One is by waging war. But fortunately war is becoming more and more suicidal. Another is by great programmes of peaceful work carried out by the state. I suppose the construction of the cave temples at Ellora occupied as large a fraction of the labour of the subjects of the Rastrakuta kings as that of guided missilles does of the subjects of Queen Elizabeth II, and there was a lot more to show for it at the end. Scientific research is already absorbing an appreciable fraction of all the labour power of the Soviet Union, and a somewhat smaller one in the U. S. A.

No health or happiness without work

I do not think wealth and leisure are much of a danger unless in the name of freedom the state permits advertisers to make people discontented. Nor are they if those who have leisure know a little elementary physiology and psychology. I do not suppose that my acquaintances are deliberately trying to shorten my life by making me take a motor car rather than walk half a kilometre, or a lift rather than go up two flights of stairs. However attempted murder of this kind is regarded as courtesy. I can't work for as long hours as I did when younger, and until my bones have mended I don't propose to work much over forty hours a week. But if I settled down to talk about my neighbours, read novels, play cards, and listen to the radio, I think I should be near madness at the end of one year, and hope I should be dead at the end of two. If I were a poor and illiterate villager, but with a pension to live on or a child to feed me, I could find enough to do mending roads and paths, cleaning out water courses, and so on. I am not talking nonsense. During the last monsoon I must have dumped a lot of broken bricks into holes by the roadside near my place of work, which were full of water and a nuisance to pedestrians. I prefer outdoor work of this kind to Gandhian spinning, but that is a matter of personal taste.

By all means let us take occasional holidays. But I do not think that the Prime Minister's fears will be justified if it is possible to persuade people that the man or woman who can work and does not in digging his or her own private hell.

In Europe one takes various components of European culture for granted, but on migrating to India I am beginning to see them in their proper perspective. I have been teaching science for just forty years, and it was a shock to me when I found that my basic assumptions about such teaching do not work in India.

I was walking near my house one Sunday afternoon when I heard a male voice raised in a monotonous chant. I supposed that I was listening to some mantras, and asked my companion if he could identify them. The practice of repeating religious formulae is of course about as common in Europe as in India, and I have little doubt that it has an effect in guiding the thoughts of the chanter in certain directions, even when the chanting has become quite automatic. It is not so sure that it guides them towards the kind of experience which a few holy men all over the world have shared, even though they described it in different words, or stated that it could not be described in words.

But my companion stated that the language of the chant was English, and the subject organic chemistry. We returned, and I found that he was right. The subject of the chant was the preparation of aliphatic amines, with special reference to various precautions. I have learned a great deal in this way, and have a very considerable stock of poetry, in at least ten languages, and eleven if you consider, as I do, that some parts of the Koran are great poetry. Clearly one must learn poetry exactly. A change in a single letter may make a lot of difference, as is clear if, for example, you substitute "bottle" for "battle" in English verse. As I think war is more pernicious than alcohol, I am in favour of this change, which has very pleasing results, such as

"Turn, if you may, from bottles never done,
"I call as they go by me one by one".

But I have never learned any scientific fact in this way. On the contrary, I try to learn them in as many different ways as I can and to teach them from many points of view. For example in teaching medical students about the parts of the human heart I tried both to make them imagine where these parts were within their own chests, and what course the blood took through them. In teaching statistics I try to jump from the durations of human lives to those of safety razor blades and back, to encourage a similar agility of mind in my hearers.

The knowledge of science is, or rather should be, something quite different from the knowledge of poetry. The more you can alter the symbols, the more you are likely to grasp the reality which they represent. I offer this argument, for what it is worth, to supporters of Hinduism against other religions. Whatever its truth in the religious sphere, it is certainly true in science. It is even desirable to get to know a familiar object by as many senses as possible. One should know the commoner birds of one's neighbourhood by ear as well as by eye, and some of the mammals also by their smell. When I learned comparative anatomy we students first learned to identify bones by looking at them ; then we handed a bone to a colleague under a table, and he tried to identify it by feeling.

The kind of knowledge which is most useful in science is a very long way from that which gets one a first class in a written examination. I am remarkably ignorant of many facts which some of my junior colleagues know. But I know where to look them up, though unfortunately some of the books and journals are not available in India. What is even more important, I know fairly well what is not known. When one of my young colleagues made what turned out to a completely original observation I said that I thought nobody had ever noticed such a thing before, and told him to write to two men in Europe and U.S.A. to confirm this. Much of my success in research has been due to my knowledge concerning human ignorance. So far as I know this peculiar kind of knowledge is never taught.

But the most important part of science, in my opinion, is not knowledge but method. Scientific method cannot be explained, but only demonstrated. Research is rather like poetical composition. There are rules for both, but you will not become a poet at all, let alone a great poet, by adhering to the rules. Nor will you make great scientific discoveries by following "scientific method" as laid down by writers on that subject. Both the great poets and the great scientists adhere to the normal canons as a general rule, but do not hesitate to violate them from time to time. Their violations may sometimes become the canons of art or science in future ages. More often, like the Lord Krishna, they should be admired but not imitated, if only for the simple reason that to obtain a novel result one should break a rule which has not been broken before.

The divergence of my attitude from that of some of my colleagues is well shown by their habit of asking me on what problems I am engaged. Occasionally in the past I have tried to get the answer to a definite question, but not very often. And when I did I generally found the answers to questions which I had not asked. For example in trying to make myself more alkaline I altered the responses of my nerves and muscles to electric shocks in a peculiar manner, in seeking for an equation which would describe the action of enzymes acting on their substrate at a steady rate. I found the equation which describes what they do in the first second, when the rate is increasing rapidly. As a general rule I am not interested in a problem, but in an animal, a plant, or a process. I have very little idea which will come out of my investigation.

Obviously I cannot ask a student to work in this way. He or she must be given a definite task which I can be fairly sure will lead to definite results within a year or two, in other words a "problem". My father started me off in this way. But I always leave students time to spare to study subjects of their own choice, though of course I may tell them that this investigation would take ten years, and that one has been done already. If a research student had not, in three years or so, strayed from the rather narrow but safe path which I had laid down, I should not think of recommending him or her for a research post.

I am quite aware that this would not be possible if the research depended on the use of a large telescope, an atomic reactor, on some other expensive apparatus. But even there I should hope that the student would start on some original theoretical work.

As I see it, science is an attitude, not a set of facts. If you are interested in frogs, cyclic ketones, pulsating variable stars, or whatever it may be, you will certainly want to find out what is known about them. And you will hardly be interested unless you know something. It is not sufficient to be interested. Your interest may lead you to write poetry about frogs, as Dante and Clare did. If it is good poetry, this is better than bad science. But your interest may lead you to discover new facts about frogs rather than to express your emotions about them in memorable words. If you can do this you are a scientist.

You may of course discover facts without being interested in them, as you may add up columns of figures in an office or make pottery or shoes in a factory. But you will only make beautiful pottery if you are interested in what you are doing or keep very strictly indeed to tradition. Even if you are in charge of a machine you are much more likely to do your job well if you are interested in the machine.

I am inclined to think, therefore, that the word "Science," though it is not grossly misleading in Western Europe, may be so in India. I do not know how it is translated into most Indian languages. But I should like to see it translated into a word or phrase meaning "Interest in Nature", or perhaps better "Interest in prakṛti" for as I understand it, the word prakṛti covers those aspects of human minds which can be the subjects of scientific investigation.

I am beginning to understand why my students here think I am being funny in lectures when, for example, I refer to his Highness the Governor of Mysore in a lecture on biological variation. I do so because he is a very large man without being disproportioned, and because some of them must have seen him. If they or I had seen Agastya I should certainly refer to him also as an example of variation in the opposite direction. They cannot believe that I am happier because I have seen so remarkable an example of the possibilities of the human body. Perhaps if they ever come to believe it they will be on their way to becoming scientists.

SCIENTIFIC EXPLORATION : UP AND DOWN

A Lot of money and effort is being spent in getting men as far up as possible, and also in producing machines which will send information back to earth. Less effort is being spent in getting down. This is a reversal of the course of history. There were miners and divers long before there were balloonists, aviators, or even mountain climbers. Even fifty years ago more people had been a mile below the earth's surface than a mile above it. Let us see what some of the difficulties are both in going up and down.

Probably Gagarin's first appearance in an Indian examination paper, though I do not think his last, was in a question set by me at the Indian Statistical Institute. I asked how long he could have lasted without any oxygen supply. The answer depends on many things, for example, how big was his 'capsule', how much oxygen he used per minute and whether the capsule was full of air or of oxygen.

To be on the safe side, I supposed that Gagarin used 25 litres of oxygen per hour. Very likely he used under 20, for he is a small man, and was apparently quite comfortable and relaxed during his journey through space, doing little but eating and turning a knob occasionally. And the less work a man does, the less oxygen he uses up.

If his capsule had a volume of about 4 cubic metres, or 4,000 litres, the use of 25 litres per hour would lower the percentage of oxygen by about, 0·6 per cent. After eight hours it would have dropped by five per cent. If he started with air he would have been with 16 per cent of oxygen, which is quite enough for very light work. After twelve hours the oxygen would have been down to 13.5 per cent, the carbon dioxide would have risen to about 6 per cent. He would have been panting heavily as the result of the carbon dioxide, and rather stupid and confused as the result of the low oxygen.

The unpleasantness of such gas mixtures has been greatly exaggerated. I have managed to sleep, though rather fitfully, in air containing five per cent of carbon dioxide from my own breathing. In about eighteen hours Gagarin would probably have been dead. As in fact his voyage lasted under two hours, there was no need for him to take any oxygen or carbon dioxide absorbent. I do not think the volume of the capsule could have been under two cubic metres. If it was as low as this, the above times would all be halved.

It is possible that the capsule was filled, not with air, but with pure oxygen. If it was, some risk was run, for in pure oxygen not only do wool and human hair burn, but so do iron and many other metals. A meteor or a spark could set the inside of the capsule alight. In pure oxygen he would have lasted a little longer. After twenty-four hours he would still have had plenty of oxygen left, but the carbon dioxide would have risen to twelve per cent, and he would probably have been unconscious, certainly incapable of skilled work or thought. There is little advantage in starting with pure oxygen.

In any long stay in a closed space, whether in space or in a submarine, it is necessary to replenish the air with oxygen and take out the carbon dioxide. Unless the air is also dried, everything soon gets very wet. When the oxygen comes out of a cylinder, it is easy to arrange for it to drag about forty times its volume of air through a mixture of lime and soda. This would keep the carbon dioxide steady at about two per cent. If the oxygen jet only pulled ten times its volume of air, the carbon dioxide would rise to eight per cent which would be almost unbearable.

This simple method was quite satisfactory for miniature submarines. One tried to keep down the bulk, but weight did not matter. In a spacecraft weight is more awkward than bulk. Thus liquid oxygen can be stored in a light container, while compressed oxygen requires a heavy steel cylinder. So liquid oxygen may be best in a spacecraft, and compressed in a submarine. A number of chemicals, such as sodium peroxide, which unites with carbon dioxide and gives up oxygen, have been tried. Perhaps one of them has been found to be suitable for spacecraft. They were not so good as compressed oxygen either for mine rescue apparatus or for submarines twenty years ago.

For a voyage of several days, for example round the moon and back, the amount of oxygen in the craft when launched is quite unimportant. It will only last for eight hours or so. The rate of supply is what matters. The smaller the crew, and the stiller they can keep, the less they will use. That may be one reason why the Soviet planners are said to be going to send up a woman shortly.

For a voyage to Mars or Venus and back, which would take many months, it will probably be best to use a biological method of regenerating the air. It will be bubbled through a tank containing green algae, which will absorb carbon dioxide and produce oxygen. They will be exposed to very intense sunlight and very high amounts of carbon dioxide. They will have to be specially bred to be efficient in these circumstances. The race to produce suitable algae will perhaps serve as a test of the relative values of Michurinism and Mendel-Morganism. On the whole I think the Americans will win the race, though not by many months.

I don't know what the sky and earth look like from a spacecraft. But one of the most impressive sights that I have so far seen is an underwater cavern into which I had crawled in a diving dress, and which was lit up by a powerful electric lamp which I carried. It was a limestone cave, and the walls were covered with tiny crystals which shone like the jewels in the underground treasure house of a story. I would sooner go two hundred miles down than up, if I could.

A few people have gone down for several miles in the sea in a pressure resistant bathyscaphe. But they have seen no more, in fact less, than was revealed in photographs of the ocean floor at still greater depths. Nobody has gone down as far as even two hundred metres in a dress exposed to water pressure, though they could, I think, go to four hundred or so,

Judging from what have been found so far, there may well be some quite unexpected types of animal living at great depths, but the exploration below the earth's surface is likely to be much more interesting. One again it is likely to be a very long time before a human being gets down for twenty kilometres.

However borings may reach this moderate depth in a few years. Oil wells, have reached eight kilometres, but as the cost increases more rapidly than the depth there is no great economic urge to develop quite new methods. Soviet workers have however developed a quite new method in which the rock instead of being filed away with a ring of small diamonds set in steel, is broken up by condenser discharges.

The reason why it is scientifically worth while drilling to as little as twice the present record depth is this. The continents consists of a layer of granite which may be covered by a thinner layer of sedimentary or eruptive rocks. Below the granite is a layer of basalt. However under the oceans there is generally no granite, and the basalt layer is thinner. The basalt seems to end abruptly at what is called the Mohorovicic discontinuity. The Yugoslav geophysicist Mohorovicic (the last two consonants are ch) found that the speed of propagation of earthquake shocks suddenly increases at a depth which is 30 to 40 kilometres under the continents, but is sometimes as little as 7 under the oceans.

Nobody knows what is under the discontinuity. It may be a chemically different sort of rock, or it may only be denser than that above it because it has been altered by high pressure. A group of engineers in the U.S.A. propose to bore down from a Ship, probably of one of the West Indian islands. Boreholes for oil have been made from ships, but so far only in shallow water, and there may be unforeseen difficulties.

Doubtless Soviet engineers are tackling the same problem. So far as I know they have not discussed how and where they will try their deep bore. They are often blamed for this. I can assure my readers that it is the normal practice in scientific research. I don't tell the press what I am trying to do unless I am so sure of success that it is hardly worth doing, I tell a few colleagues.

Though a borehole may get down into the earth's so-called mantle, below the discontinuity, in the next five years, I do not think that a man will do so in this century. And the centre of the earth will be far harder to reach than the surface of Saturn or even Neptune. I have enough faith in man's engineering powers to believe that at least an instrument will one day reach it. But that day is many centuries ahead. Meanwhile even a gram of rock from below the basalt layer may give us information which will help us to predict, and thus to avoid earthquakes.

SCIENTIFIC KNOWLEDGE

Problems of Dissemination

Most readers of this article derive their knowledge of science from two sources. On the one hand they may have read some books and attended some lectures with a view to passing examinations. They have also read a number of popular accounts of science such as the present article and visited museums or exhibitions. Very few indeed have read what I should call a serious scientific book, nor do they read any scientific journal consistently. They are a very long way from the source of knowledge. And very often they do not understand how scientific knowledge grows.

The first stage consists of notes made in the field or laboratory. They may be rough, but it is absolutely essential that they should be clear not only when the worker writes them down but when he or she reads them several years later. These notes may be random observations such as "19/9/60. 14.53 hrs. J.B.S.H. saw three *Catopsitia pyranthe* (a butterfly) flying over plot 12". Or they may be notes made as part of a plan, for example, "11/12/60. Weight of green paddy from 12D, 247.3 tolas". Very often such notes are copied at once into a substantial and well-bound notebook.

Secondly these notes are tabulated and classified. Perhaps the paddy from 48 plots has been weighed, and in these plots four different varieties of rice had been planted. Of the twelve plots devoted to each variety four were untreated, and two other sets of four treated with different amounts of ammonium sulphate. If so it will be desirable to draw up a table with three rows and four columns. Then it will be easy to see whether for each variety the yield goes up with the amount of ammonium sulphate added, or, which is quite likely, the yield falls in some varieties. At this point graphs may help the research worker to see what is happening.

The third stage is a careful analysis of these results. We find, say, that a particular treatment raised the yield of Randhani Pagal rice by 27 per cent on average. But the effect was not very regular, and it might have occurred by chance with a probability of about seven per cent. It will be well to repeat these experiments over several years before publishing.

The fourth stage is publication. It is quite common to publish a short preliminary account in a journal such as *Nature*, *Current Science*, or *Science and Culture*, and a more detailed one in a journal which publishes longer articles, such as the Proceedings of the National Institute of Sciences of India, or the Journal of Agricultural Research. Some scientific results of real value are published in official documents. They are often inaccessible to foreign scientists working in similar fields if only because scientific libraries do not suscribe to them.

I edit the *Journal of Genetics*, which publishes original research. Some of the papers submitted are quite unsuitable. I recently rejected one of about ten pages simply recording that the authors had failed to get any seed on crossing two plant species. They had not found out where the block occurred. Perhaps the pollen grains of one did not sprout on the other. Perhaps seeds were formed and did not develop. But readers were not told. Other papers are unintelligible. Or perhaps I think I can understand them, but am fairly sure that most readers will not. Other authors insist on saying everything three times over and drawing graphs as well as making tables to describe the same results. When I try to reduce their length they think I am spiteful. In fact people are very unwilling to read long papers unless their content is particularly interesting, and an author who compresses his result is much more likely to get an international reputation than one who covers a lot of paper with them.

I trust that I have never rejected a paper offered to the *Journal of Genetics* merely because I disbelieve in the author's conclusions. I have rejected some because their conclusions did not seem to follow from the facts presented, a very different matter. But a scientific editor must realise that in rejecting what he thinks is nonsense he may be rejecting work which is too original for him to understand. Just for this reason teachers, students, and above all, journalists, must not believe that because a paper has appeared in a reputable scientific periodical, its conclusions, should be taken as generally accepted, let alone true.

When I was a professor in London I thought that my main jobs as a teacher were two. First I tried to introduce first year students to the subject which I taught. Secondly, I tried to give the advanced students a summary of work too recent to have got into any text-book. If I thought that my topic was well treated in a text-book, I told my boys and girls to read it. But a text-book is generally five or ten years out of date, and no self-respecting university should base its course on text-books.

Besides text-books there are several other kinds of scientific books. There are books dealing with a rather restricted field of science, such as my books on enzymes and biochemical genetics. In these books I did not try to summarise all work which had been done in these fields, but all which I thought important. Of course I was often wrong in my judgements. Such books as these are read mainly by professional scientists. A few great monographs, generally written by groups of specialists, may be valuable even after a century. Thus, *The Flora of British India* was published between 1872 and 1897. It is still indispensable, though it requires a great deal of revision. One of the task before independent India is to write an up-to-date account of our plants. Most books of this sort become out of date in ten years or so. Students should always look at the date of a scientific book before they read it.

Among the scientific books which are reasonably up-to-date are books of Tables such as Kaye and Laby's Physical Tables. The demand for them is big enough to make frequent revision worthwhile. The same is true for Salim Ali's admirable *Book of Indian Birds*, of which each edition is better than the last. The most up-to-date books of all are probably quite cheap books in the Penguin and similar series. For example in my opinion the best book on Darwinism is John Maynard Smith's *The Theory of Evolution*. Such books should be in every university library. But they are not.

Many popular books on science are extremely bad, and as they are praised by ignorant reviewers they often achieve wide sales. Others are not without merit. But it is very hard to judge. Finally, science fiction sometimes, but very rarely, achieves the advancement of science.

The use of a library is a very important part of university education in Europe. Students learn how to find books and use periodicals. If they are merely directed by lecturers to consult a particular page they learn very little. They must be able to go to shelves and look at books. My own library has been so open to students for several years, while that of the Indian Statistical Institute is not. I have lost fewer books per year than I did in London. The losses included translations of the *Kamashastra* and *Anangaranga*. I suppose the thief was less ashamed to steal these works, of which the former, but not the latter, seems to me a real contribution to knowledge, than to buy them. Shame is a strange emotion.

I notice another difference between university libraries in India and England. When I used that of University College, London, there was a stern door-keeper who checked the books which I took out, to verify that I had signed for them. He knew quite well that I was a professor. He also knew that professors may be absent minded, if not dishonest. On at least two occasions I have been lent books from an Indian university library without signing for them. Once such rules are broken, even on behalf of vice-chancellors or ministers, books will begin to disappear on a large scale.

It is quite impossible for any one man to choose the books for a library. A committee of a dozen or so specialists is needed and even so mistakes will be made. In a properly constituted college or university the library committee is one of the bodies to which distinguished scholars are appointed, while finance and the like are left to less intellectual persons. The librarian must of course exercise his discretion. The professor of Sanskrit might like a monograph on Tokharian B (an ancient Aryan language) or the professor of zoology a French monograph on crustaceans. But the librarian must ask whether anyone else will read them. If not, they should probably be refused. On the other hand, a professor may want books which are likely to help students, but not scholarly enough for his own use. A good library committee can and does arrive at a compromise in such cases. But a librarian should be a man of wide knowledge and strong character.

I have seen a number of university and college libraries in India. In most of them some sections have seemed to me about as good as could be got with the money available while in others money was clearly being wasted. In America, and to a less extent in Europe, there are microfilm services. If one knows the title of an article, or even a book, one may be able to get a microfilm of it. I am perhaps an oldfashioned conservative, but I am against spending great effort of a microfilm service for India. Indian scientists are apt to be rather narrow specialists ; and considering their poor opportunities for reading this is no wonder. They should, therefore, be given every opportunity for browsing among books and journals.

I have written this article because so many Indians seem to think that seience can be adequately disseminated through text-books and lecture. This is not so. I have never attended a lecture course on genetics except those of my junior colleagues in London. And my only interest in text-books is which to reccmmend to my students. We have got to get scientific knowledge over to some millions of Indians. For this purpose we must use all the possible methods of spreading it, and not just one.

SOME RECENT ADVANCES IN HEART AND BRAIN SURGERY

Roughly speaking there are three kinds of surgery. The first and best kind aims at leaving the patient as he was before, except for a little scarring. For example if one removes a bullet or a wood splinter the tissues around it may heal perfectly. If one brings the ends of a broken bone together and binds them firmly in position with a splint, they may heal together perfectly. If one joins the end of a severed nerve the fibres may grow down their former paths, and sensation and power of movement may be fully restored to a hand or foot. The second kind of surgery removes or destroys some tissues which has been gravely diseased, for example the vermiform appendix or an ulcerated stomach. All successful operations for cancer are of this character.

The third kind of surgery removes, destroys, or damages tissue which is apparently perfectly healthy, for the benefit of the whole organism. It is always suspect, but may sometimes be justified. The operation of frontal leucotomy, which means cutting some of the nervous paths in the front of the brain, was very popular in the treatment of lunatics some years ago. It certainly makes them less troublesome to the authorities in lunatic asylums, and even to their families. But it is said that the operation leaves the patient incapable of thinking or acting for himself. Fortunately it is becoming less popular as much the same results can be obtained with tranquillizing drugs, one of which, reserpine, is a traditional Indian remedy.

In this article I shall write of the remarkable claims made by American surgeons for two operations of this kind. In

India a large number of distinguished men die round the age of sixty of coronary disease of the heart. The main symptom is intense pain in the heart, usually accompanied by a quite irrational terror. I have had the terror without much pain, as the result of experiments. I suppose one can learn to overcome it, but I at least would much sooner try to cope with a severe pain. After a number of attacks of angina the patient dies. The condition is due to blocking or narrowing of the coronary arteries, which supply blood to the various parts of the heart.

Professor C. S. Beck, of Cleveland, Ohio, U. S. A. studied a large number of human cases, and experimented on thousands of dogs. He found that while in a few cases most of the heart muscle died, a good deal could die and be replaced by fibrous scar tissue without causing death. The usual cause of death was fibrillation, that is to say irregular twitching of small fibres which ought to contract simultaneously. This is not a rare event in ordinary muscles. Sita experienced it in an eyelid muscle during her captivity in Lanka. But if it happens in the heart it may prevent its beating and cause pain, distress, and finally death. Beck found that this happened when one part of the heart had a good supply of oxygen and the neighbouring part had none. It did not happen when both parts were equally well supplied, or equally badly.

It is not yet possible to open up a blocked artery in the heart, though this may be achieved later. So Beck devised the following operation. He opens the chest wall by separating the fifth from the sixth rib, and norrows the coronary sinus, by which blood leaves most of the veins draining the heart muscle. He scrapes the surface of the heart and the pericardium, the membrane round it, blows asbestos powder on the raw surfaces and fixes them together. This causes the formation of new blood vessels which partly supply the areas which should be fed by a blocked artery. The supply of blood to the whole heart is cut down to about half, and what does get in is evenly distributed. The patient can often get out of bed the day after the operation, and in nine cases out of ten the pain ceases and the patient can live a nearly normal life. Two cases out of the last hundred and fifty two operated have died. Of course we do not yet know how long the others will live. But at the age of sixty, five years of pain-free life are worth having. In view of the commonnesss of angina in India we may hope that some Indian surgeons will learn to perform this operation.

The other operation, due to Professor I. S. Cooper, of New York, is of a more surprising character. By no means a rare affliction of old age is Parkinson's disease, which is characterized by involuntary movements of the hands and other parts, and a rigidity of the face muscles which gives a peculiar mask-like appearance. These symptoms are caused by over-activity of a group of cells in the middle of the brain called the globus pallidus. It is far from clear why they are over active. It seems most likely that in this and related diseases they are no longer being controlled by the parts of the brain outside them. However that may be, their destruction puts an end to the symptoms and seems to have no harmful effects, But how to get into the middle of the brain without causing very grave damage was no simple problem. The first step is to blow air into the ventricles inside the brain through the back of the neck and after X-ray examination of the patient to trace lines on his scalp to guide the operator. The patient is then anaesthetized and a small hole bored in his skull. A hollow needle is introduced through this hole, and its progress watched by means of X-ray photographs until its point is judged to be in the right place some three inches inside the head. The patient is then taken back to his room with the needle in place, and allowed to get up next day. A day or so later alcohol, usually with a little celloidin in solution, is injected. Such injections go on for a week or two until the symptoms have disappeared. If necessary a second needle may be inserted. The needle is usually only pulled out when cure is fairly complete. Dr Cooper claims that on his last hundred cases the rigidity has absolutely disappeared in ninety, and the trembling in eighty, while the others at least improved, and none have died. However two have developed paralysis on one side. One very well known Indian clearly suffers from Parkinson's disease, and I venture to hope that the operation will be tried on him. It was not. He is now dead.

It seems to me that this gives us a glimpse of the surgery of the future. In more and more conditions it should be possible, instead of opening up the patient, to introduce an instrument into him which will do the required job with the minimum of damage. It is remarkable that one can put a needle through the cortex of the brain without any detectable harm. This could not be done in all parts of it. A needle in the cortex at the very back would cause a small blind spot. But the part of the brain concerned in memory and thought acts as a whole. Though if it is damaged on a large scale, mental functions are seriously and permanently disturbed, no one part of it is essential for a particular purpose. The heart can be reached by pushing a rubber tube up an arm vein, and watching its progress with X-rays, and this can be used in treating disease of the heart's valves. As time goes on it will be possible to reach more and more organs in this way. Let me add from my own experience that once a needle is through the skin it causes no pain except when it punctures a rather small number of sensitive structures. I have only had hollow needles stuck into me for reaserch purposes, apart from those stuck into veins when I have given blood. And some patients find it frightening. But as time goes on I hope that it will be as common an experience as a cutting operation under anaesthetics is today. It will certainly be a great deal safer.

Our knowledge of the relation between mind and brain grows very slowly. There are two reasons for this. We cannot ask the right questions. Whatever may be the nature of the relation it cannot be the same as that between two material objects, for example, water in the jar which holds it, or between two conscious beings such as a ruler and a subject. So the kinds of precise thought which characterise most of the sciences on one hand, and law on the other, will not help us. I think it very possible that the minds of human being can be regarded as illusions resulting from ignorance. However we must describe these illusions as best as we can.

Secondly, we have not the right to experiment with human minds or brains as freely as with other parts and functions. Even if neurologists were permitted to injure the brains of condemned criminals I do not think they would do so. A neurologist who did not realise that an executioner is at least as severely damaged as the man whom he kills would be so bad a psychologist as to be unlikely to find out anything of interest.

So, although we can learn something from experiments on animals, which however, often cause some damage to the experimenter, much of our information comes from brain surgery. Fortunately for the progress of science this generally includes some experimentation. Except in the rare cases where the operation is merely the removal of a tumour or a splinter between the skull and the brain, it is part of the practice of brain surgeons to stimulate the exposed brain surface electrically. For example if the operation is being done to cure the unfortunately rare type of epilepsy which can be so cured, a part of the brain is stimulated so as to bring on epileptic fits, and the most sensitive region is cut out. During and after any cutting of the brain photographs are taken, and the tissue removed is examined under the microscope.

Brain operations are now seldom done under a general anaesthetic. This is partly because they often lost a very long time, and many people who recover after an hour of ether anaesthesia would not recover after six hours. It is partly because an important function of anaesthesia is to cause relaxation of muscles, for example in the abdominal wall, and this is not needed in brain surgery. And it is partly because a conscious patient can give the surgeon important information. So the skull and other tissues outside the brain are numbed with a local anaesthetic.

Cutting or electrical stimulation of the brain surface never causes pain. Pain is felt with a part of the brain far inside it, and at present inaccessible to surgeons. Some parts of the brain surface are concerned with muscular movements. In human beings the hand muscles, the eye muscles, and those concerned in speech, occupy most of the area. For these are muscles over which we exercise far more detailed control than over those of the trunk and legs. Electrical stimulation of these areas causes involuntary movements. Near to the motor areas are the main sensory areas. Again the hand is represented by as large a brain area as the whole trunk. Stimulation of these areas gives rise to feelings of touch or numbness in the corresponding parts of the body. Vision has a special area at the back, and hearing at the sides. However most of the brain surface is "silent". Its stimulation produces no obvious effect. Areas near the main sensory areas are concerned with co-ordinating sensations. Thus when a silent area near that whose stimulation causes sensations in the hand has been damaged by a bomb splinter, the patient can still feel touch on any part of his hand, but cannot tell whether he is grasping a coin or a match box.

This has been known for forty years. More recently an area just behind the forehead has been shown to be concerned with personality. If the fibres in it are cut, violent and intractable patients may become quiet and co-operative. One particular part of it, the cingular gyrus, seems to have a very remarkable function. This has been removed in some patients dying of a very painful inoperable cancer. The patients say that they are still aware of severe pain, but it does not distress them. Nor does the thought that they will be dead in a month. It would seem reasonable to say that this area was the seat of what Indian philosophers have called *ahankara* the sense or illusion—of personal identity. Naturally enough, operations or injuries in this region may have very undesirable effects. Some victims appear to lose initiative completely. For example, a woman could not decide on what to serve as a meal, but could cook it satisfactorily if someone else made the decision.

The most recent addition to our knowledge is described in a paper read to the Washington Academy of Sciences last year by the eminent brain surgeon Penfold, who was one of my fellow workers in Sherrington's Laboratory in Oxford thirty-seven years ago. In the course of operations on fully conscious patients he has frequently stimulated areas on both sides of the brain which had previously been regarded as "silent", with the following results. Sometimes the patients were conscious of an event in their past in very great detail. For example one woman heard a musical piece being played by an orchestra. She thought it was coming from one of the pieces of electrical apparatus in the operating theatre and was able to hum some of the tunes. She remembered when and where she had heard it before. Others lived again through emotionally important events in their lives. The second effect was a feeling of recognition of their immediate perceptions as having been experienced before. These two experiences are essential components of human memory, though Penfold never elicited both of them together.

I meet a man whom I have not met for several years. I recognise him as some one whom I have known before. I then remember that when we last met he was wearing a gold-edged lungi and told me about tobacco growing in Madras State. I may have the memory of past events before or after I have the recognition of the face, But both are needed for satisfactory memory. I am not satisfied if as is often the case, I merely remember that I have met the man somewhere before. In English we use such words as "Memory" and "Remember" very loosely. Thus I may say that I remember a piece of verse, meaning that I can recite it, I do not necessarily remember when, where, or how I learned it. In other languages the distinction between true memory and capacity for a performance is more clearly made. If we learn more about the physiology of memory we shall probably be able to make more useful distinction between the various meanings of this word.

Penfold does not think that either the recognition of present experience or the recall of past ones is due to activity in the part of the brain which he stimulated. As a general rule, electrical stimulation of a part of the brain does dot give a detailed action or sensation, Electrical stimulation of the speech centre may force the patient to produce a prolonged vowel sound, but not a sentence or even a word. This is natural enough, for a great many cells are stimulated at once, and there is no proper pattern of action. But stimulation of one part may occasionally evoke a clear pattern of action or sensation in another part. Penfold, therefore, thinks that the actual seat of memory is elsewhere. He has merely stimulated nerve fibres which send messages to another part of the brain which bring stored memories into consciousness. I think he is probably right, but most of the facts about cerebral localisation can be interpreted in a less materialistic way, as Bergson tried to do in his "Matiere et memoire".

What is quite certain is that philosophers ought not to ignore these facts. If for example they hold to analysis of the human mind given in the samkhya philosophy, they should at least realise that the different constituents of the mind described in that philosophy are associated with different parts of the brain. Lenin wrote as follows : "It is, of course, totally absurd that materialsm should maintain the 'lesser' reality of consciousness or should necessarily adhere to a mechanistic world picture of matter in motion and not an electro-magnetic or even some immeasurably more complicated one". My own guess is that our most useful world picture a century hence may include at least some elements of the samkhya picture, matter being a good deal more like prakiti according to Kapila than like the picture common when Lenin wrote. But we shall certainly not reach a true picture by ignoring facts such as I have summarised in this article.

Statisticians are not usually very adventurous people, perhaps because they are more interested in means than extremes. However every six months the N. S. S. must provide adventure for a few workers who find that they have to go to remote viliages in the mountains of Himachal Pradesh or the jungles of Mysore. My own work has been only statistical in part. Nevertheless I began to contribute to statistical research at a very early age. My father invented a number of methods for physiological measurements. Among these was a haemoglobinometer with which one could estimate the amount of the red pigment haemoglobin in human blood. A drop is quite sufficient, but sixty years ago British people were as averse from giving blood as some Indians are now. As "Student" had not yet published his great paper, my father did not know how many subjects were needed before he established with reasonable certainty that adult bloods contain more haemoglobin than those of children. I think I was the first child whose blood he sampled. But there was some difficulty in obtaining enough children, and my sister was heard to remark to another little girl in the street. "You come in here, my father wants your blood."

Later on I contributed numerical data on other physiological characters. But many of my father's experiments were too drastic to be done on large groups. So were some of my own. For example I ate about 15 grams of salt before going to bed, with no water. By the morning my kidneys were concentrating chloride to about .31 molar. On taking another 15 grams in the morning the concentration only rose to about .33 molar. Only four or five people were tested in this way, but their concentrating power varied from under 0·3 molar to over 0·4. I do not know whether I shall be able to obtain volunteers for this form of **tapas** in India. Intense thirst is not pleasant, and it requires a certain concentration of mind to resist it.

During the 1939-1945 war I was engaged in physiological work for the British navy. Unfortunately naval officers do not understand statistical principles. They asked me some questions which I could answer, for example, "How much compressed oxygen and soda-lime mixture are needed by two men if they are to keep alive in a miniature submarine for 48 hours, doing very little work." This question can be answered because the oxygen consumptions of different men at rest are not much more variable than their weights. By staying shut up with a colleague for the requisite time I convinced them that it would be safe for others. They next asked me how long a man can safely breathe oxygen at various depths under water. This knowledge was needed for the men who proposed to put bombs under the German battleship Tirpitz, wearing self-contained diving dresses. Oxygen is poisonous at high pressures, causing convulsions which can be quite unpleseant and are followed by unconciousness for five minutes upto half an hour. Sometimes there are warning symptoms, sometimes not. We soon found that the time before the onset of convulsions fell off rapidly as pressure increased. At depths over 40 metres they often occur in less than five minutes, and may be so violent, at least in my own case, as to break bones.

But different people seemed to vary a great deal in resistance to oxygen poisoning. I say they seemed to, for the navy not unnaturally did not wish to frighten men who had volunteered for a dangerous job by giving them convulsions. To determine whether one could trust the result of a single test we did a series of 17 experiments on my wife who breathed oxygen at a standard pressure until she had a convulsion, or she or the man observing her thought she was going to have one. The times which she lasted varied from 13 minutes, ending in a convulsion, to 92 minutes, with nothing worse than twitching. Only one sailor beat this. My wife's times had a very positively skew distributions.* Alltogether she has had five convulsion from high pressure oxygen, with no worse injury than dislocations of the jaw. It was clear that one could not give a definite answer. We suggested that after a previous test to weed out the most sensitive men one could cut down the risk of a convulsion, which would mean almost certain death under water on active service, to about 1%. However the British naval authorities were not at all satisfied with this answer.

You see that some kinds of statistical investigation involve some discomfort and even risk. For I must admit that I was never quite sure that my wife or I would be pulled out in time if we had a convulsion under water. This Institute is surrounded by objects which are a challenge to statisticians, and whose investigation will involve some risk. I refer to the palm trees of various species. It may be possible to measure the yield of a cocount palm (**narikel**) without climbing it. But some day, and the sooner the better, an attempt must be made to breed for high yield. Now if we plant the nuts from a tree we know their mother. But we do not know the father, that is to say the tree which provided the pollen to fertilize the nut. Statistical work on the inheritance of yield can only begin when a geneticist can climb the coconut trees to make the required matings. I at least would feel safer 30 metres under water than 30 metres above ground on a swaying palm.

In my opening sentence I wrote that statisticians are

* For the benefit of non-statisticians, I explain that this means that a few times lasted much more than the average, and many a little less.

usually more interested in means than extremes. I am exceptional. I have just taken up the problem of the distribution of maximal values in samples where Fisher left it thirty years ago. And I think I have shown that maximum value of the square of a normal random variable has a much simpler distribution than the unsquared maximum. Such intellectual adventures are doubtless a poor substitute for having convulsions under water. But they are better than nothing.

There are several schools of Buddhism in Japan. It may well be that some of these are as far from the sermon in the deer park at Kashi as the practice of the Church of England is from Jesus' sermon on the Galilean mountain. I shall not discuss this question. The Zen, or meditative school, is divided into two sects, of which the Rinzai claims that samadhi can be achieved by meditation on what is called a Koan, and probably mistranslated into English as a riddle. One of the seventeen hundred Koans is called "The sound of one hand." The guru claps his two hands, and then asks his disciple to concentrate on the sound of one of them. It is said that if one has grasped the meaning of this phrase he has obtained enlightenment, and is no longer under the bondage of such notions as "I" and "mine."

To most Europeans, and perhaps to most Indians, this must appear to be nonsense. In my opinion it is not non-sense, but good modern physics. I only disagree with the Zen teachers in thinking that it does not necessarily lead to enlightenment, though I think that it may do so. The sound made by one hand is not an observable, that is to say it is not an object of any of our senses nor can it be detected or measured by any instrument. Nor are the psi waves which, according to some attempts to put a mathematical theory into words, are in some sense the basis of material events and objects.

Let us see how scientists are led to think in terms of unobservables. I begin with a very simple observation. If you go out before dawn you will see very little colour. As the light increases you will see green leaves and blue or yellow flowers for some time before you see red flowers. You have the same restricted colour sense as the kind of colour blind men called protanopes. Colour is so obviously dependent on the conditions of lighting and those of the eye and brain of the beholder that some European philosophers called it a "secondary quality", as compared with "primary qualities" like size and shape and "tertiary qualities" like dissonance, which depend in part on education, for Indians find some sound sequences melodious which are not generally so regarded in Europe. From Newton to Planck physicists tried to explain secondary qualities in terms of primary ones, and they had some success. A red object can be defined as one which when light is shone on it, absorbs light of certain wave lengths more readily than that of others.

The attempt to explain colour, warmth, sound, and so on in terms of atomic structures and movements is part of the search for invariants, that is to say properties which are unaffected by changes in the observer or his language. For example the difference between two weights is not the same if we measure them in seers or in tolas, but their ratio is unaltered. The numbers of atoms of various kinds, namely hydrogen, oxygen, sodium, and chlorine are not altered when a lump of salt is dissolved in water, but their pattern is altered. And we may say that it has altered because the observer has got older.

The notion of an invariant was first made precise in mathematics. We can write down the equation for a curve such as an ellipse. We can then ask what algebraical expression remains constant if the position of the ellipse is altered provided its shape and size remain the same. This is not a very difficult problem. It is a little more difficult to answer the question of what is invariant in the set of all paths, in space and time simultaneously, possible for a lighter body moving round the sun, if we give a rough solution ignoring the pull of the planets. It is very much harder to answer this question if we allow for the gravitational pull of the planets.

From a mathematical point of view the search for "laws of nature" is a search for invariants. A big step towards invariance was made when Einstein formulated the special, or restricted, theory of relativity, which allows us to describe large scale events in a way which is invariant if an observer is moving at any constant velocity. The general theory, which holds when an observer is changing his velocity, is still incomplete. The difficulties of describing small-scale events are much greater, because the act of observing a system changes it. We can only see an object if it alters the course of some ray of light from what it would have been were the object not there, and much the same is true for the other senses. If the object is small enough the light will alter its state of motion, and we cannot simultaneously measure where it is and how quick it is moving. Because the act of observation alters a material system, any objective account of it, that is to say any account which is the same for everybody, whether or not they are observing the system, must be in terms of unobservable events or objects. This does not mean that materialism has broken down. The opposite is true. Two conscious beings cannot experience the same small-scale event. So any attempt to describe the world in terms of experience common to several conscious beings is bound to be inaccurate. Idealism will not work on the atomic scale. But the situation for materialists is not simple either. In Lenin's words, or rather those of his translator "The sole property of matter, with the recognition of which materialism is vitally concerned, is the property of being objective reality, of existing outside of our cognition." The best account of objective reality, in this sense, which mathematical physicists can give us is in terms of the probability of a particle being in a given small volume during a given short time. This is a long way from the mechanistic materialism of textbooks of elementary physics. It is perfectly compatible with Lenin's view when he wrote "It is of course totally absurd that materialism should maintain the 'lesser' reality of consciousness or should necessarily adhere to a mechanistic world-picture of matter in motion and not an electro-magnetic one, or even some immeasurably more complicated one".

If I wanted to develop the analogy of the two hands in the Koan, I might try to explain how a pair of conjugate complex quantities, as mathematicians call them, occur in modern descriptions of "objective reality". But it may be more illuminating to describe the actual history of the discovery of the particles called mesons. When electrons are surging backwards and forwards in a metal rod they generate radio waves, which in turn can make electrons move to and fro in a radio receiving antenna. The electrons in an atom are also believed to be moving quickly, but they do not generate observable radio waves or light. Yet the fact that they are attracted to the positively charged atomic nucleus can be explained if they are exchanging flashes of light, or photons as they are called with this nucleus. These photons are unobservable. If they exist they are private light, so to speak. An atomic nucleus consists of a number of particles, some with no electric charge, some with a positive charge. It would fly apart unless there were some very powerful force holding it together.

Yukawa, a Japanese mathematical physicist, showed that the particles would hold together if they were exchanging particles whose mass he calculated roughly. He did not, so far as I know, suggest that they could be observed. It would be most interesting to know whether Yukawa was directly influenced by Zen Buddhism. Of course no cultured Japanese can avoid being influenced by it indirectly. Some years after Yukawa's publication a study of so called cosmic rays, more accurately very quickly moving particles from outer space which are constantly entering the air, showed that after collision with atoms in the air, they generate particles whose properties agree with those postulated by Yukawa. They are now called mesons from a Greek word meaning middle or between, because their masses are between those of an electron and a nucleon, that is to say one of the components of an atomic nucleus. There are several kinds of mesons, and the kind which Yukawa imagined only lasts for about a fifty-millionth of a second on the average, when it turns into a somewhat lighter and stabler kind. However it makes its existence known in other ways than by holding atomic nuclei together.

This is quite typical of how physics progresses. Objects are postulated to explain some observed fact. Thus atoms were postulated to explain why, for example, the weight of oxygen per unit weight of carbon is twice as great in one of the more easily prepared oxides of carbon as in the other. But it was nearly a century after Dalton put his atomic theory forward that individual atoms were seen by the flashes which they make when moving very fast. Of course a good many of the objects which physicists have imagined, and which have helped them in their work, such as tubes of force and electronic orbits, have not made good their claim to reality. I do not think that some more modern conceptions, such as molecular orbitals, have much of a future, useful as they are at the moment.

Let me end up with one more example. A Zen guru might ask a pupil to contemplate the wings of a caterpillar. A caterpillar has no organs of flight. But it has what are called imaginal discs which are groups of cells which will develop into wings if the caterpillar lives. I have little doubt that when we know more we shall be able to make a caterpillar develop wings without altering its other structures. Professor Maheshwari and his pupils in the Department of Botany at Delhi are already doing something of the kind with plants.

To come back to the sound of one hand, sound is a form of energy, and each hand possesses energy of motion just before they meet. When they meet, some of this energy appears as sound. The better we understand the transformations of energy, the nearer we are to enlightenment, for the more ludicrous do our "common-sense" notions of "I" and "mine" become. I know that it is not fashionable to suppose that the study of material happenings can lead to enlightenment and liberation. We are enjoined to study science to improve the means of production. This is no doubt one reason for doing so. Perhaps it is not the most important.

KEEPING COOL

In northern India we had in 1958 the hottest summer for thirty years. The monsoon arrived late, but brought cool air. However in Bengal we are not getting our usual share of rain, and the weather is getting warm again. Where I work there is usually no serious problem in keeping cool, for we have plenty of good electric fans, and I seldom have to work out of doors between 10 a.m. and 3 p.m. But my wife has to teach a class whose members look at small living insects through microscopes. If fans were turned on, or even if the windows were opened on a windy day, the insects would be blown away. So she and her pupils have to put up with the same conditions as ordinary people.

The problem of keeping cool has been thoroughly studied in England in connexion with the ventilation of mines and factories. It has been little studied outside them. No doubt the Americans claim to have solved the question by air conditioning. But this is very costly, and one feels the heat intensely out-of-doors on leaving an air conditioned room. It is time that a serious and scientific study were made of this question in India. In England we know the temperatures which people prefer if they have a choice. We also know the temperature at which accidents are fewest in some kinds of factories. For they increase in frequency at higher or lower temperatures than about 13°C. At higher temperatures it seems likely that workers get sleepy and lethargic, at lower temperatures their fingers may get numb and they are more likely to drop things. If workers are given a choice, they usually like to work at a temperature a little above that which reduces accidents to the lowest level. I do not doubt that in India the best temperatures would be higher, except perhaps for very hard work indeed.

How do we keep cool in hot weather ? The answsr is not at all simple. Perhaps the first thing of all is to wear sensible clothes. I am writing this in a pair of cotton shorts and no more. Soon, in deference to other workers here, I shall cover up most of my body. I regard this as needless concession to custom, in either sex. A generation ago women in many parts of South India were not ashamed to show their whole bodies above the waist. And in Europe a mother may feed her baby in public without blame. This is particularly common in France, and thus men are not violently excited by what they see. However I do not claim the right exercised by the poor and the holy, to work or walk in a dhoti or shorts. But I do slightly pity my male colleagues who wear a cotton vest under their shirt or kurta. And my wife, who wears a very opaque cotton blouse, a black skirt, and little else, pities her Indian colleagues who wind themselves up in a number of layers of cloth. No doubt some of them pity her for wearing black like a catholic nun, and carrying no jewellery.

In the course of a day a man in India who is not working very hard produces about 2500 kilocalories of heat, that is to say enough to heat 100 kilograms of water through 25°C. If his heat capacity is equivalent to 50 kilograms of water this means that if he lost no heat at all his temperature would rise about 2°C per hour. So in two hours he would have a pretty severe fever, and in three or four he would be dead. Besides this a man may gain a good deal of heat from the sun which he must get rid of if he is to avoid a rise of temperature. The human body can lose heat in two ways, by warming air and evaporating water. The latter is much more efficient. To get rid of 100 kilocalories per hour one must warm about 270 cubic metres of air through 1°C, whereas only 170 cubic centimetres of water or 4 litres per day need be evaporated.

If the air is cooler then the human body, it can carry away some heat, even if it is so moist that it can take up no more water. Hence a fan or a breeze has a cooling effect. If the air is also dry there may be a lot more cooling from evaporation. If the air is hotter then the human body it will heat it, but if the air is dry so much heat can be lost by evaporation that a man can keep cool. My father, who studied this matter about fifty years ago, remained for 32 minutes in a room where the air temperature was 83°C, or 182°F, but as the air was fairly dry, his temperature only rose slightly. The temperature of a wet bulb thermometer, that is to say a thermometer whose bulb is wrapped in a wet cloth, and cools itself by evaporation, as a man does by sweating, gives a fairly good measure of the effect on a man. If the wet bulb temperature rise above 31°C a man is in danger of death from heat stroke in still air, but in a good air current he can stand 34°C. However if he is working even moderately these temperatures must be lowered by three or four degrees.

When the air is hot and dry an air current cools him as long as any sweat is left on his skin. But if the air current is strong enough to dry him, any further increase will bring more heat to his body from the air, without any increase in the rate of heat loss. That is why people go indoors if they can during a hot dry wind such as the lu of northern India.

Cows and horses sweat much like men, but dogs, for example, do not. When a dog is hot it produces a lot of very watery saliva, and breathes very quickly. There is enough evaporation from the mouth to keep it cool. But in hot dry air a fan is of no use to a dog, though it would be to a cow. Insects, on the other hand, do not sweat. Unless they have a good supply of water to drink they are killed much more quickly by hot dry air than by moist air at the same temperature. They simply dry up. This is why there are so few during the hot dry weather in India.

I hope that twenty years hence most villages in India will have electric power and that by that time most households will have enough money to buy an electric fan. But before that time

I also hope that at least as much research will have been done on keeping cool in India as has been done in Europe. The first subject for such research should be the kuskus, as in this part of India we call the wet curtains used to cool air in the dry weather. They cool the air by evaporation. But I am sure that the air currents used with them are usually too weak or too strong to produce the greatest possible cooling effect. I could doubtless frame a theory of cooling by this means, but I know from long and sometimes bitter experience that in such cases theory is no substitute for experiment. Perhaps an equally important topic is the physiology of babies in hot weather. Even in Europe a fair number die from water loss in hot weather. We do not know how far the cooling needs of babies differ from those of adults. In a recent lecture to a medical society I pointed out the need for such research, and the fairly obvious fact that it must be done in India since a European mother would not allow her baby to be exposed to the temperature prevailing in U. P. in May. A newspaper reporter accused me of demanding experiments on Indian babies. The experiments are done on lakhs of babies every year, and some die in consequence. But as nobody measures the temperature rise, water and salt loss, and so on, of babies, they die in vain, and more die next year.

There are plenty of other topics to be investigated in connexion with keeping cool in India. None of them demand expensive apparatus. But they cannot be done in a hurry, and they must be done in a number of different parts of the country, for the problems of Madras and Delhi are obviously different, for example the kuskus is much more use in Delhi than in Madras. I hope that this article may encourage some of India's young scientists to tackle this important question.

DRUG-RESISTANT BACTERIA

I read that some highly placed people in India are drawing attention to the existence of races of bacteria which resist antibiotics, and the dangers of their spread. I am slightly amused when correspondents inform the public that this is a recent discovery, since I was certainly referring to it in popular articles before 1940, and have since written a scientific paper which perhaps makes its investigation a little easier.

The drugs to which resistance develops very frequently are the so called antibiotics such as sulfaguanidine and penicillin. These all seem to act in much the same way. Their molecules are built on nearly the same plan as molecules of an essential foodstuff of the bacteria. They are like enough to unite with the enzymes which transform the foodstuffs into living material, but they cannot be utilized. So if enough of an antibiotic is added, the bacteria behave as if starved of a particular food stuff. They may be unable to grow, or they may grow abnormally, and die. If however we supply a large amount of the substance of which the antibiotic is a dummy, the bacteria can start growing again. This phenomenon is called competitive inhibition. So far as I know it was discovered by Armstrong in 1904, and named by myself in 1930, so it is not very novel.

The action is quite different from that of an ordinary poison such as mercuric chloride, sometimes called "corrosive sublimate". This unites with a variety of enzymes, but cannot be crowded off them by adding food stuffs. Let me try to draw an analogy. If I wished to paralyse the economic life of an Indian city I might fly over it in an aeroplane scattering false one rupee notes, like enough to the genuine ones to deceive the public, but not like enough to deceive bank clerks. This would cause great confusion, and make it hard to use the genuine notes.

If bacteria are subjected to these competitive inhibitors, whether in a human patient or in a culture in a laboratory, new races may arise which are more or less resistant. The most usual, though not the only way, in which this occurs, is the selection of individual bacteria which have varied in such a way as to become resistant. The idea that this happens arouses quite heavy emotional resistance in some biologists not only in the U.S.S.R. "Variation", they say, "is a random process, a matter of chance ; so you are reducing natural selection to a combination of chance and killing". The answer to this criticism is that variation is only a matter of chance in that I cannot yet predict that the third seed in an ear of rice will give a plant with green leaves and the fourth one with purple leaves. I can predict that about a quarter of the seedlings will have purple leaves. I cannot predict their arrangement in an ear, and I do not think anyone else will be able to do so for many years to come. What sort of variation will occur is as predictable and intelligible as any other biological event. Sometimes we know enough to predict it very accurately, more usually we can only do so roughly.

The sort of variation which is selected varies considerably. Sometimes the bacteria actually come to require what was a poison to their ancestors, and die when it is no longer supplied to them. More usually they alter their chemical process so as to produce a needed substance by a different method from their ancestors.

However some bacteria adopt themselves much as a man, by practice, can learn to lift weights which he could not lift at first. One bacterial species can learn to produce an enzyme which destroys penicillin. The learning process has been studied in great detail by Pollock, using penicillin containing radioactive sulphur. This enables us to measure extremely small amounts of it. Each bacterium, for every molecule of penicillin is fixed to it, produces a new molecule of enzyme about once in 90 seconds. If the penicillin is washed away, it makes no more of this enzyme, but what it has made is gradually divided among its progeny. So the capacity to destroy penicillin is lost after ten generations or less. This is rather like what happens in a human society when any branch of art or knowledge becomes purely traditional. One certainly needs tradition, but if one has nothing else, a time comes when posterity copies every attribute of a great man except his greatness.

There is no doubt that in countries such as the U.S.A. and England where antibiotics are used on a large scale, drug-resistant bacteria are now much commoner than they were when the drugs were first used. However it is doubtful if they will replace the original types. For resistance is only achieved by an alteration in chemical make-up which is somewhat wasteful in the absence of the drug, and therefore resistant races can rarely if ever spread in competition with the more sensitive types so long as they are not being selected by the drug. The danger is much greater in a country like America where penicillin is used in a great many unnecessary cases than in one like India where it is very rarely used even when it could save a life. It is less in a country where the medical service is mainly nationalised, as in Britain, than in one where doctors have a financial interest in supplying needless drugs.

Fortunately, perhaps, another danger may help to cut down the needless use of penicillin. So far as I know no case is recorded where a dose of it killed a man or woman who had never had a dose of it before. But it has killed a fair number of people who have had one or more previous injections, and become sensitive to it. So doctors will become more careful of prescribing it unnecessarily.

I do not think we can lay down a correct policy at present. Ideally, when a powerful drug is discovered which will usually destroy the bacteria causing a disease, or better, when several such are found, a worldwide campaign should be made to wipe out the disease for ever. This is not possible until the whole world is economically developed to the stage where it can be done. In India a great and fairly successful effort is being made to make malaria into a rare disease. But it would not be worth trying to abolish it altogether unless this were also being done all over the world. In many African countries, for example, no serious effort has yet been made to prevent malaria. Nor can success be hoped from such an effort until enough Africans have been educated to lead their own peoples in the fight.

I am sure, however, that even if a few private medical practitioners in India use antibiotics when they should not be used, the country as a whole needs enormously more than are available. Certainly we should accept "aid" in the form of such drugs from any foreign state which will let us have them, while I fully agree with the policy of our Government in refusing to accept weapons which may only "aid" armies to assume unconstitutional power. But we must make our own antibiotics, and I hope that our third five year plan will provide a larger increase of factories for this purpose than did our second. The danger of excessive use of these substances, which may be a real one in the U.S.A., is still very remote in India. And I hope that by the time it is a real danger our medical service will have been nationalised at least to the extent that this has been done in Britain. As I pay a weekly subscription to the Medical Unit of the Indian Statistical Institute, for which I get most satisfactory service, I am not recommending to others a course of action which I do not take myself.

Mr. Selwyn Lloyd, the British Foreign Secretary, is reported to have said, when informed that a missile launched in the Soviet Union had reached the moon "I don't think many people are terribly interested in it". This is as appalling a comment as could be imagined on the kind of people Mr. Lloyd meets. I hope it will lose his party a million votes in the coming election. For the people of Britain ought, quite literally, to be "terribly interested". For if a missile cannot merely hit the moon, but a region of it determined within 200 miles, as has been stated, it can probably hit a target in England with an error of one mile. Curiously enough this probably makes the people of London a little safer. In the last war the Soviet bombs, unlike the British and American ones, were mostly dropped on targets of military importance. And in a war with Britain the first few hydrogen bombs would probably be directed at rocket launching sites and aerodromes rather than cities. Some are so near to London that a bomb burst over them would cause very heavy damage and casualties in London, but would probably leave most of its inhabitants alive, and possibly somewhat critical of their government's foreign policy.

Mr. Eisenhower, who has commanded a great army, knows that wars are now largely decided by technical equipment. So I have no doubt that he is interested. But Mr. Lloyd apparently thinks that he is Lord Palmerston or Sir Edward Grey. He is not. People are no longer "terribly interested" in British foreign secretaries, because successive British governments have thought other matters more important than scientific teaching or research. I was in Malaya recently, and saw the colossal effort devoted by the British government to hunting down a few hundred communist rebels. These men and women have now mostly been killed or captured. But the money spent on liquidating them could have trained some ten thousand engineers, who are considerably more of an asset in any future war than Singapore was in the last war or is likely to be in any other. In other words this small group, even if they have personally been defeated, have won a major victory for communism.

Mr. Lloyd and his acquaintances are no doubt genuinely uninterested in nature, and cannot understand why other people are so, except perhaps in so far as money can be made out of it. Even if the Soviet missile had done no more than reach the moon, it would have made a notable contribution to science. If the report is true that a Hungarian astronomer has seen a dark circle spreading out on the moon from the point of impact and lasting for an hour it tells us a very great deal. Many astronomers think that the relatively flat parts of the moon, called Maria, or seas, which they certainly are not, are plains covered with dust from the disintegration of rocks by the alternation of heat and cold, and the impact of meteorites. Now a projectile hitting a plain covered with dust would doubtless raise a dust cloud ; and on earth such a cloud might remain for some hours. This is because the dust particles are raised very quickly, but fall very slowly through the air. But if there is any gas round the moon, its density is probably less than a millionth of our own. Particles of dust too small to be seen would therefore fall back as quickly as large stones. I only know of one agency which would keep a cloud of dust suspended above the moon's surface for an hour, in the absence of air. That is electric charge. A cloud of particles all with the same electric charge would stay up for a long time, because each would repel the others. Only the particles on the surface of the moon can be charged, but once they are thrown upwards they may acquire a charge very rapidly under the influence of the X-rays and ultraviolet radiation from the sun, which are stopped by the upper layers of our own air, and produce the charged regions which reflect radio signals.

It has been calculated that a meteorite displaces about sixty thousand times its own weight of material. As the lunik weighed four hundred kilograms, it would displace about twenty four thousand tons of lunar material, and if even a third of this went up, it would form a considerable cloud. It may be possible to photograph the crater formed by the missile. This can best be done when the sun is nearly setting or just risen in the area of the moon concerned, for then shadows are long. In other words the area of impact should be observed when it is in the bright part of the moon, but near to the dark part. Perhaps the next good opportunity may be when the moon is waning. Anyhow we shall get some information about the moon's surface, including perhaps valuable data as to the possibility of making a relatively gentle landing on one of the seas of dust.

But it is more certain that we shall get a lot of information about the space between the earth and the moon. Has the moon got a magnetic field like the earth and the sun, not to mention a few stars whose magnetism is far more powerful than the sun's ? We now know that its magnetic field is far smaller than the earth's. Nobody knows the cause of the earth's magnetism, but it may be due to electric currents eddying in its metallic core. The moon is much less dense than the earth, its average density being just sixty per cent of the earth's ; and it probably has no metallic core. If the moon is a magnet at all comparable with the earth we shall have to scrap the theories about the magnetism of the earth and the stars which are at present most popular.

We shall also get a good deal more information about the charged particles which have been caught in the earth's magnetic field and are moving in various orbits with very high speeds. The existence of regions in which such particles are moving was predicted by Stormer, a Norwegian physicist, in 1911. However his calculations were wrong in detail, though Chapman in England later predicted the correct distance from the earth, and American popularizers write of "von Allen radiation" after an American worker who deduced their existence from the signals of American satellites. Whether they were first discovered in the U.S.A. or the U.S.S.R. I do not know. There is a substantial agreement about their existence and properties. Human beings who are shot up far above the air will need protection against them. But their study is important for other reasons.

Much of our knowledge of the fine structure of matter is derived from the study of what, in my childhood, were called vacuum tubes, but which in fact contain gas at densities which are low by the standards of the earth, but very much higher than in the space between us and the moon. In such tubes electrically charged atoms and molecules can move for fairly long distances without collisions, and display properties which were previously unsuspected. Nowadays we can make them move in nearly circular orbits in cyclotions and similar expensive apparatus, where the path length may be some kilometres. But in the space between the stars they can travel for years without collision. In these circumstances they may be expected to show new kinds of behaviour, as men do when they isolate themselves from contact with their fellows.

In the last twenty years a new branch of physics called magneto-hydrodynamics has developed. It treats of the motions of charged particles in magnetic fields, and may be going to explain a great deal about the observed structure of stellar systems. It is not only difficult mathematically. It is as yet based on regrettably few observations and still fewer experiments. The ‘sputniks and luniks are signalling back results which will play an important part in the development of this science. The American propaganda service claims that their satellites are provided with apparatus so much better designed than those in the Soviet satellites that they furnish more information, though lighter. This may or may not be true. What is certain is that much of the information on these matters from the Soviet Union which reaches the Indian press is grossly distorted, perhaps in translation, and the Soviet authorities concerned could do worse than improve the information service from Moscow to India, however good that from bhuvaloka to Moscow may be.

There is perhaps an even simpler reason why it is scientifically important to have hit the moon. It is a concrete proof that certain physical "laws" or rules about the behaviour of matter hold good at least as far as the moon. Some of these rules break down at very small distances, others at very large ones. Others may be superseded by unexpected properties of matter at intermediate distances. The fact that we can plan and carry out a journey to the moon, so far only by machines and not by men, makes it much more likely, but not certain, that we could send similar missiles to Sukra or Bṛihaspati without taking hitherto unknown agencies into account. If we had got that far, it would not prove that we could send them to distant stars.

Some Indian politicians have spoken rather flippantly of this work. I think they may not realise its scientific importance. Personally I think that biological research is even more important both practically and theoretically. The next few months will show whether I am right or wrong in my beliefs as to what kind of research is practically important. But biology is not so useful as physics either for making profits or for killing people. So it has not got the same prestige in the present human society.

It is now officially announced that the dog in the sputnik is dead. Either there was no way of sending her down, or the device for doing so did not work. English dog-lovers protested to the Soviet embassy. I have yet to learn that English bird-lovers protested to Mr. Macmillan against exploding thermonuclear bombs over the sea, where they must kill many thousands of sea birds outright, and many thousands more in a slow and painful manner.

I cannot blame the people who sent Laika to her death for a very simple reason. I should have been quite ready to take her place. Though in fact I am much too heavy for the job. If a human volunteer is sent up in another sputnik with a small chance of coming down again alive, or with none, it should be some one weighing less than myself, and preferably with incurable cancer or some similar disease, but not too ill to report back until they die.

I do not know how the dog Laika felt

> "When her virginal feet were set
> On the terrible heavenly way."

Dogs usually enjoy experiments. I have seen one in a laboratory at Leningrad pulling a human assistant along a corridor in its eagerness to act in an experiment of the Pavlov type on conditioned reflexes. There is no reason to think Laika felt any great fear or pain at any stage.

I probably know better than anyone else in India how a human volunteer in a similar position would feel. Of course I have never chosen certain death, but I have often chosen a fair risk of death. This produces a feeling of exaltation which makes it hard to give an objective account of what is happening. A soldier's account of his first battle is probably quite unreliable.

The first possible danger to a passenger arises from acceleration. If a man is being pushed violently his blood tends to remain behind. If he is being accelerated hand first, his blood tends to collect in his feet, and he may faint. If he is accelerated feet first it is forced into his head, and a blood vessel in his brain may burst. If however he lies down he can stand an acceleration of five or six times that due to gravity for a minute or so. All this has been worked out both in aeroplanes and in centrifugal swings.

After a few minutes at most of violent acceleration the sputnik is launched in its orbit, and is in a state of "free fall", the earth's pull on it being balanced by the centrifugal force with which it is

"Struggling fierce towards heaven's free wilderness".

(I apologize for possible misquotations for Swinburne and Shelley. My books have not yet arrived from London.) The passenger has no weight. There is no up and down for him or her. Men have experienced this state for times up to about 20 seconds in diving aeroplanes. Some were upset by it, some enjoyed it. But even the latter might develop symptoms like sea sickness after a few hours. If Laika did not, this is a valuable bit of knowledge.

The nearest condition to weightlessness which I have experienced is life in a flexible diving suit in which ones head is enclosed in a waterproof bag, not a metal helmet. The tendency of the blood to run into ones head, which is so unpleasant when one hangs head downwards in air, is completely counterbalanced by the increased pressure of the water. One of my colleagues could go to sleep under water with his head downwards. I never did, but my last dive was in a cave where I had to go down a narrow vertical shaft from which water was rising, for about fifteen feet head first, before starting to crawl along the channel through which it came. This is no harder than riding a bicycle, but of course it needs some practice.

In such a dress one still knows which direction is upwards, from small organs inside the ear containing heavy particles. But this knowledge makes little difference to ones feelings or actions. And a diver soon learns to screw up the valve through which air or oxygen escapes until his net weight is only five or ten pounds, and another turn of the screw would inflate his dress so that he floated up. I would recommend any intending passenger in a sputnik to spend forty-eight hours or so lounging under water in a flexible self-contained diving dress.

Laika was very possibly supplied with food and drink by injections. In the absence of gravity one cannot pour water from a bottle. A human being should probably take it from a bag with a porous mouthpiece. However breathing is much more of a problem. Here too I can speak with some personal experience. I have been shut up in a metal box with no means of renewing or purifying the air till I was nearly unconscious, and have often lost consciousness from lack of oxygen or excess of carbon dioxide. I have also been shut up with a companion for forty-eight hours in a metal chamber which was in fact a compartment of one of the miniature submarines used by the British navy during the second world war. (Many writers write war with a capital letter. I regard this as the sign of a devotion to Skandha which I do not feel.). We had adequate supplies of oxygen and of an absorbent for carbon dioxide, and suffered from nothing worse than cold, wet, and stiffness. For the compartment was not very large, and we could not both stretch our legs at the same time.

If one is on the way to dying from lack of oxygen, one pants, but not very violently. If carbon dioxide is also accumulating, as it does when one is shut up without any absorbent, one pants very heavily. But there is no pain, and one gradually falls asleep. I have also been buried alive under sand, and had to breathe through very narrow tubes or cotton wool pads.

This is most unpleasant. I felt as if my chest would burst, and in fact partial obstruction of the breath has been used as a torture. But provided one can breathe freely, the panting is no worse than after running a mile or so. I would far sooner die from exhaustion of the air in a confined space than from most diseases.

When black mice were sent up in American balloons with adequate oxygen supply to a height of twenty miles they developed some white hairs at their next moult. They had been hit by atomic nuclei moving with very nearly the speed of light which went into their tissues and killed all cells along their tracks, including some of the cells making black pigment. These atomic nuclei came from outer space, and are stopped by the relatively thick air of the lowest twenty miles. Their properties have been studied from the tracks made when they penetrated piles of special photographic plates. I don't think such particles could kill a dog in a week. They might reduce a man to stupidity in some months, and impair his vision. Space ships may have to be built with very thick metal walls to keep them out.

Why have the Soviet Union achieved this wonderful result when the United States are well behind them, and other governments have not even tried ? No doubt the Soviet system is specially favourable to large scale engineering, but the Vedas give another reason. "Devas tam parāduh yo nyatrātmano devān veda", the gods desert him who knows the gods nonspiritually, I read in the Bṛihadaranyaka Upanisad. The Americans are constantly repeating a formula stating that God is in heaven, and it must influence their thought even if they do not believe it. They might do better to say that heaven was in God, though this too seems to me a crudity. If you think of the sky as God's special abode, you are likely to be inefficient in dealing with it. Perhaps I am old-fashioned in thinking that mantras are important. But this seems to me to be a case where they have had some historical influence.

Yuri Gagarin is perhaps the most famous man in the world today. And it is good that such a man should be famous. For millions of boys all over the world must want to tread *"On the terrible heavenly way"* which he has opened, and if they cannot be the first to get above the air, or even to reach the moon, may hope to be the first to land on Mars or on an asteroid. And it is easier to try to imitate Gagarin's good qualities than those of the mathematicians and others who made his achievement possible.

It is obvious that Gagarin is a brave man. But there are several types of brave men. To judge from his appearance, which may be very misleading, and his few recorded sayings, he is of the type which, when exposed to danger or pain, behaves with complete calm. He probably did what had to be done almost exactly as he had done it in practice at ground level. There is another type of brave man or woman who is often rather unreliable in normal life, being prone to accidents, encounters with the police, and so on, but is at his or her best in a dangerous or at any rate frightening situation. I chose such people as colleagues in underwater work twenty years ago.

Unforeseen

Perhaps the extreme example of such a man in literature is Dolohov in Tolstoi's *War and Peace*. I wanted these qualities because we were working with makeshift machinery, and all sorts of unforeseen things went wrong. For example the first time I got out of a miniature submarine under water, I had practised opening the lid of the escape chamber in air, but when it was flooded under water there was a lot of oil on top of the water. I was wearing an escape apparatus, and when the water rose over my head and I tried to turn the wheel to open the lid, I found it covered with oil and my hands slipped. I was quite frightened, as I had no means of communicating with others. I finally got the lid open and recommended changes in the design including a milled edge to the wheel.

I have no doubt that all the apparatus which Gagarin had to use had been tested many times under all kinds of stresses, and the various ways in which it might go wrong were pretty well known. If so the calm type of courage was needed. But when the first human party lands on the moon they may be exposed to unforeseen dangers, and I hope they will include at least one man with the good qualities of Dolohov, or at least of Denisov.

Gagarin is also no doubt an intelligent man. But I am sure he is not a man whose intellectual processes interfere with his practical activities. I hope that one of the next astronauts will be a poet, but if so he must have an unimaginative companion who will turn the necessary handles while the poet is trying to find words for experiences which no human being has had before.

Acceleration

Gagarin was also no doubt chosen for his physiological capacities. When going up and coming down he was subjected to intense accelaration. He lay with his body at right angles to the direction of acceleration, or most of his blood would have been forced into his head or feet. But even so the strain may have been considerable. I have no doubt that a large number of people were tested for resistance to acceleration, and that Gagarin was one of the most successful ten per cent.

I have also no doubt that he is a good all-round athlete. He was also, I think, chosen partly because of his small weight. Had I been in charge of the choice, I might have recommended a woman on this ground. Gourage of the Gagarin type is quite common in women, though most frequently evoked by threats to their children.

For more than an hour he was subjected to a condition which no one had experienced before for more than a few seconds, namely weightlessness. Even if his craft was spinning quick enough to force him gently to one side, he must have felt as if he were falling. Now when most people are subjected to abnormal episodes of falling and rising they get seasick. It is possible that normal people would be in this distressing state after half an hour's "free fall."

I have found that I can usually prevent sea-sickness or air-sickness for an hour or so by controlled breathing. I breathe regularly and deeply at intervals of ten seconds or so and this holds off vomiting. But it is quite possible that Gagarin was chosen because, among other things, he was immune to seasickness. If so, it is very important to find out whether in less well qualified people weightlessness leads to vomiting or any other symptoms.

I do not doubt that Gagarin was tested by exposure to various kinds of stress. Heat and cold were doubtless included, for a space-craft is bound to be heated while moving very quickly through the air on its way up and down. And while circling round the earth it will pass about half an hour in intense sunlight, and almost as long in intense cold.

Provision is, of course, made to keep its temperature steady, but it might go wrong. One's reactions to heat and cold depend largely on the control of the heart and blood vessels. They are not directly under conscious control, but the mind certainly influences them.

Similarly he was no doubt tested with psychological shocks such as loud sounds, flashes of light, and so on, to see that they neither affected his heart nor stopped him doing a job. In both these sets of tests he was probably helped by joining the Communist Party, as he has recently done. The acceptance of Marxism leads to the disappearance of certain kinds of worry, which may play a part in causing gastritis, anomalous heart beats, and so on. And membership of the party might suffice to give an extra few minutes' endurance of extreme hardship.

Experiment

If I had been in charge of his training, I should have tried another experiment on him. I would have shut him up with no supply of oxygen or means of absorbing carbon dioxide, until he lost consciousness. If carbon dioxide is removed, one loses consciousness gradually without any discomfort. But if carbon dioxide accumulates, one pants very hard indeed for some time. This is not painful, but can be alarming. Gagarin's reactions to these stresses would have been noted.

If the arrangements for returning him from his orbit had broken down, he would have died from want of oxygen or excess of carbon dioxide. And, as he is a brave man, the knowledge that it is a painless form of death would have helped him to go on reporting calmly to earth if he believed that he would not come down again alive. Fortunately these tests, even if they were made, were unnecessary.

Above the atmosphere there is a variety of radiations and of quickly moving particles which are stopped more or less completely by the air. If we lived on the surface of the moon we should doubtless be resistant to them. But, in fact, they are harmful to us. Some of these rays and particles, such as X-rays from the sun, and electrons discharged from the sun or moving round the earth, are fairly completely stopped not only by a space craft's metal skin, but by its window which lets light through. However some particles, and particularly the nuclei of atoms heavier than hydrogen, are moving so fast that they can not only penetrate metal plates, but in doing so produce showers of other particles such as mesons.

No doubt Gagarin was partly protected against these particles, which are misnamed cosmic rays. But unless discoveries of an unexpected kind have been made about them in the Soviet Union, and kept secret, which I greatly doubt, the protection was not complete.

I think that in the next few months Gagarin is likely to develop a few patches with white hairs where a rapid particle has killed the pigment-forming cells. These have been seen in mice which have been for some hours at great heights. I have little doubt that physicians are examining Gagarin's skin for other possible effects. They are not likely to be immediately serious.

Blind Patches

Again small blind patches may have appeared in his retinae, the light-sensitive membranes at the back of his eyes. They are not likely to spread, and are quite harmless, as we all have large "blind spots" already, which we do not normally notice. But if he has got even a few blind spots in one hour in space, there may be a danger of total blindness in a three years' voyage to Jupiter or Saturn.

He is probably a little more likely than before he went up to develop certain kinds of cancer. Space travel may be as dangerous as cigarette smoking from this point of view. And high energy particles seem to have a general aging effect. He may have diminished expectation of life by a week. This is not a serious matter, but the effect of a year's voyage in space might be very serious indeed. So the medical examinations to which he will be subjected for the rest of his life may be of great importance to future space travellers, even if the dogs, which were up for longer yield more information.

I make these simple remarks because I have little doubt that some people will say that the results of this wonderful feat of technology and courage can be of no scientific importance. On the contrary, they may be of value in such unexpected quarters as the studies of aging and of blindness. The knowledge that a man can behave normally when weightless, and immediately after being so, is most important, and I must confess that I had considered it possible that the first cosmonaut would be seriously affected by this condition.

It is not a chance coincidence that the combination of intelligence, technical ability, and courage needed was first realised in the Soviet Union. One of the lessons for India is this. Our educational system is modelled on that of Britain. It is unsatisfactory in many ways, and the need for reform is generally admitted. Is it not time that those who are concerned with this reform should very seriously consider copying many features of the educational system of the Soviet Union which is certainly leading the world in many branches of science ?

SOME AUTUMN STARS

Most educated people have at least a rough idea of the sun, moon, and planets, and their movements. They know very little about the background or "fixed" stars, except that they shine by their own light, like the sun, but unlike the moon and the planets, and that they are very far away. It is only in my lifetime that we have got to know much about them, and I know of no book which gives even roughly uptodate information about individual stars, though several give a general account. I am therefore going to write a series of articles about a few of the more conspicuous stars to be seen at various times of the year. I am handicapped for two reasons. I cannot ask for the publication of a star map, and I do not know the Sanskrit names of most of the stars, and only those of a few of the constellations. In Europe and North America most of the names of individual stars are Arabic, while those of the constellations are Latin or Greek. Perhaps a reader will help me with a good reference to Indian astronomical names.

What do we know about a star ? If it is bright enough to have a name, it is always near enough for us to measure its distance. This is a fairly simple matter. If we photograph the same bright star at an interval of six months, say in March and September, it will appear to have moved slightly relative to the fainter and farther stars in its neighbourhood. This is because the earth has moved relative to the sun. Half of the star's apparent movement is called its parallax. It never reaches a second of arc, that is to say the angle subtended by a centimetre two kilometres away. However it is possible to measure about a thousandth of this angle. The principle involved is the simple one which accounts for the apparent movement of a near object against the background when one shuts first one eye and then the other. However the base line is not the small distance between human eyes, but that between the earth's position in March and September, namely fifteen crore kilometres. The unit of distance is a parsec, at which the parallax of a star would be a second. This is thirty million kilometres, and it takes light three and a quarter years to travel so far. We can easily measure the brightness of a star, compared with another star, or a standard lamp at a known distance. We can also measure the heat reaching us from the brighter stars. So if we know the distance and brightness we can say that this star gives a hundred times as much light as the sun, and that other only a tenth. We can measure the temperature of the outside of a star by two methods. Cool stars are red, and hot stars blue. But we can do it a good deal more accurately by a method due to Meghnad Saha which depends on the star's spectrum. This enables us to calculate the star's size if its luminosity is known. In the case of double stars revolving round a common centre of gravity we can also calculate the mass. Finally we can measure the rate at which a star is approaching or receding, from its spectrum, and if it is near enough we can often measure how fast it is moving sideways.

Now let us consider a few of the stars visible in India in September evenings. Two bright stars are not far apart in the south, and set before midnight. These are the planet Saturn or Sone,* and the brightest star in the constellation Scorpius or Brischik, which is called Yestha or Antares. Antares is a red double star, or more accurately a pair of stars of which one at least is about twenty times as massive as the sun, and of about four hundred times its radius. However its temperature is only about three thousand degrees, or half that of the sun. But it is so large that it puts out about two thousand times as much light per second as the sun. So though it is about a hundred

* This was true in 1958.

and twenty parsecs away, it is the fifteenth brightest star in the sky.

As we glance northward along the milky way, the next very bright star to be seen is Altair, in the constellation of tha Eagle. This is one of our nearest neighbours, just under five parsecs away. It is about twenty times as bright as the sun, not quite twice as heavy, and about one and a half times as hot. With the sun, it belongs to what is called main sequence of stars. It appears probable that all stars start as members of the main sequence, in which there is a simple relation between mass and light output. So long as their interiors contain enough hydrogen their light output alters little for a time which may be measured in thousands of millions of years. Altair is a much more representative star than most of the bright ones.

As our gaze moves further northward along the milky way we see Deneb, the brightest star in the constellation of the Swan. It is so far away that its distance is uncertain, though probably about five hundred parsecs. It has by far the greatest light output of all the stars except Regel in Orion which are easily visible with the naked eye, about fifty thousand times that of the sun. Though it is only about twice as hot as the sun it has four thousand times its area. Such stars are very rare, only nine being visible, though they could be seen at a distance of five thousand parsecs, whereas the sun could not be seen at more than thirty parsecs.

Vega, in the constellation of the Lyre, not very far west from Deneb, is á main sequence star about eight parsecs away and not unlike Altair, though giving out about twice as much light. The earth's axis gradually spins round, and although it now points to Polaris, or Dhruva, it pointed approximately to Vega thirteen thousand years ago, and will do so thirteen thousand years hence. Our present pole star is about one and a quarter degrees from the pole, so that it appears to go round in a very small circle. It is a double star, and about 120 parsecs away, like Antares. However the two stars which compose it are too near to be seen separately with an ordinary telescope. They are detected as follows. If a star is moving towards the earth the light characteristic of any particular change in the electrons surrounding an atom shifts towards the violet, if it is moving away, towards the red. Such shifts occur in the spectrum of Polaris with a period of about thirty years. This is almost the same as the period of Saturn's revolution round the sun. However Polaris, though not much hotter than the sun, is ten times heavier, so the star revolving round it must be a bit further from it than Saturn is from the sun. Sirius, the brightest star, has a faint companion which goes round it every five years, and was first detected spectroscopically, and only later seen with a telescope. Probably the companion of Polaris will be detected directly in the future.

I am sure that this article has annoyed some readers. It contains too many figures. On the other hand the scientific, as opposed to the mathematical, point of view, requires some knowledge of familiar objects. The stars are among the most familiar, but what we know about them is somewhat alien from ordinary experience. Nevertheless Indian scientists, notably Saha and Chandrasekhar, have made contributions to astronomy much more important than any Indian contributions to chemistry, for example. I have therefore ventured to put a few results of modern astronomy before my readers, and hope to write three or four such articles a year, so that in the course of a year or two I shall have told them something about the thirty or so stars which, either because they are near us, or because they emit a great deal of light, appear brightest to us dwellers on earth.

Perhaps the most striking of the star groups to be seen in late autumn is the Pleiades or Krittika. Most people can see six, perhaps a few seven, without optical aid. Even a modest field glass shows many more. But the counting of them is an extremely difficult task because there are so many other stars in the same direction. In fact the Pleiades are a natural group, that is to say they are not merely in the same direction but close together. So all the stars which belong to the group must agree in four measurable characters. First, because their distances are nearly the same, they must agree in parallax, that is to say in their apparent movement against the background of faint stars beyond them as the earth moves round the sun each year. The distance is in fact about 130 parsecs, or 420 light-years. The light which reaches our eyes today started off about 1540 A. D., say about the time of Babur's invasion of India.

Secondly they must all appear, relative to their background, to be moving in the same direction with the same speed. In fact they appear to be moving to the south-east, towards a point in the southern constellation Argo. When allowance is made for the sun's movement relative to its neighbours the point is somewhat further from their present direction. A simple analogy will make the matter clear. If we watch a flock of birds flying together in the same direction, they appear to be converging towards the same point on the horizon. To a man in a moving train they would seem to be moving to a different point. Finally all these stars are moving away from us at about the same speed of 20 kilometres per second. If a star agreed with the rest in only three out of four of these measurements, it might be in the neighbourhood of the Pleiades at present, but it would have been some distance from them 100,000 years ago.

There are about 120 stars which, on these tests, are members of the Pleiades, and in addition there is a good deal of nebular matter—shining gas and dust—between them. There is plenty of evidence that such matter is associated with recently formed stars, and the Pleiades are probably less than ten million years old. It is generally thought that stars are formed from the condensation of such clouds. However at a conference held at Lucknow in 1955, of which a report has just been published by the National Academy of Sciences, India, Ambarzumian, an Armenian who is one of the leading Soviet astronomers, questioned this theory. He thinks that the nebulae may be formed by the same unknown process which also provides new stars.

However that may be the Pleiades have a wide range of luminosities. The visible ones are much more luminous than the sun, but the dimmest members so far identified are less so. And probably when still dimmer stars in this direction have been investigated a thousand or more Pleiades will be found. But as there are plenty of dim stars in their direction, new members can only be identified after careful measurements. The stars in such a cluster must be moving relative to each other, or they would fall together. If any moves too fast, it will be able to escape from the gravitational pull of the others. And this must occasionally happen when one of them acquires enough speed by passing close to several others. Such an event may occur at intervals of a few hundred thousand years, and Chandrasekhar has calculated the probable "life" of an open cluster like the Pleiades. This is certainly a good many million years, but quite a short time compared with our earth's age.

Rohini, or Aldebaran, rises soon after the Pleiades, though at present* it is less conspicuous than Mangal, or Mars, in much the same direction. It is a double star about 21 parsecs

* 1958.

away, red in colour and thus cooler than the sun, and a good deal more luminous.

Then follows Kalpurush, or Orion. This is not a "natural" system like the Pleiades. All the bright stars in it are distant, but some are twice as far away as others. However it includes some clusters. The three "stars" which form the belt are at a distance of about 200 parsecs. If they were as near as Sirius they would appear so bright as to be visible by daylight, and we should see with the naked eye that Mintaka, which rises first, was not a star, but a system of at least three stars. One is so far from the other two that there would be no difficulty in seeing them apart. However two are very close together, spinning round their common centre of gravity in a little under 6 days. These are so close that they cannot be seen apart with the best available telescopes. However the spectrum of a star gets bluer as it approaches us, and redder as it moves away ; and a large number of apparently single stars have been shown, in this way, to be double. In some cases a more powerful telescope has later enabled astronomers to see or photograph them as a pair.

The second star in the "belt", Alnilam, appears to be single, but the apparent speed at which it is moving away from the earth varies. So it probably has a faint companion. The third star Alnitak is a triple system much like Mintaka. All three are extremely hot stars emitting about ten thousand times as much light as the sun from only about a hundred times its area. The other four brightest stars in Orion are all very distant and luminous. The brightest, Regel, at the southern end, is a quadruple star. The second brightest, Betelgeuse, the red star at the northern end, is a huge object which, if it replaced our own sun, would reach nearly half way to the earth. It was the first star whose diameter was actually measured, not directly, but by using the principle of interference. Its light varies not very regularly over a period of about 6 years.

Finally in the "sword" of Orion, between the belt and the last bright star to rise, there is the famous nebula surrounding some of the fainter stars. This can just be seen with the naked eye, but is a truly magnificent spectacle when seen through an ordinary telescope. It is 400 parsecs away, further than any of the seven brightest stars of the constellation. It is a cloud of gas of extremely low density, far lower than anything obtained in a vacuum tube on earth. However it shines much like the gas in a human low pressure discharge tube, the atoms giving out what is called a bright line spectrum, so that when it is photographed or seen through a prism there are a few spots of light of different colours, instead of a continuous rainbow-like band, as with ordinary stars. The gas atoms glow in this way because they are excited by stars embedded in the nebula which probably emit enough ultraviolet radiation to do so. Some smaller nebulae in Orion merely reflect the light of neighbouring stars from dust particles. Only a spectroscope can distinguish the two types. There is reason to think that new stars are being formed in this nebula. Several rapidly moving stars now seen against other constellations are moving in paths which trace back to this region of space.

I hope that in this article I have written nothing but the truth. However astronomy is at present progressing so quickly that new facts have probably been discovered in the last few years which I should have incorporated had I known them. Perhaps Alnilam has been definitely shown to be double. Perhaps a hundred more stars have been assigned to the Pleiades. It is not easy in India to keep up with the latest news about sciences which are not ones own profession.

Soon after Orion, or Kalpurush, two bright stars, Sirius and Procyon, which in the Greek mythology are the hounds of the hunter Orion, rise in the east. Both of them are near to us, which is why they appear so bright ; and both are similar in other ways. Sirius is the brightest of the "fixed" stars, and one of the least fixed. It is so near that its light reaches us in under ten years, and its apparent motion is over two minutes of arc per century. If an astronomer who lived two thousand years ago could be brought to life he would not notice any change in the apparent shape of Orion, though these changes can be measured with modern instruments. But he would notice that both Sirius and Procyon had moved through angles of over half the moon's apparent diameter. The only other bright stars which have changed their direction more than Sirius are Alpha Centari, which is nearer, and Arcturus, which is moving very rapidly.

Sirius and Procyon are both more luminous than the sun, that is to say they give out more light, but only about twelve and seven times as much respectively. They are also about twice as heavy. We know their masses within one per cent or so, because each has a very faint companion, and the pairs revolve round their common centres of gravity with periods of fifty and fortyone years, in elliptical orbits which are much less circular than those of the planets in our solar system. So we can calculate the masses of both stars by the same methods which enable us to calculate that of the sun from its gravitational pull on the earth. These companions are very queer objects indeed. The companion of Sirius, or Sirius B, has the same mass as the sun within one per cent, and its surface is a good deal hotter. But it only gives out one three hundredth as much light and its radius is only about one forty fifth of the sun's. This means that its density is about ninety thousand times that of the sun. In other words a cubic inch of its material must weigh over a ton, and the density near the centre must be about a million times that of water. When these figures were first obtained thirty-five years or so ago, physicists found them incredible. But a number of other such stars have since been found and there seems little doubt of their truth. These stars have collapsed under their own gravitation, and it is thought that this is the normal fate of all stars when their sources of energy run down. They are called white dwarfs, to distinguish them from the red dwarfs, which also give out very little light, but are less massive than the sun, and a good deal less hot; they are not however surprisingly dense. The matter in white dwarfs is of course under enormous pressure, and we can only guess at its properties.

A sinuous line of stars stretches southward from Orion's foot to end in Achernar, a bright and distant southern star. This is called the constellation Eridanus, and contains a number of our neighbours, some of which are visible, though none is bright. The most interesting is Omicron-two Eridani, a system of three or perhaps four stars, of which the brightest has only one ninth of the sun's mass, and is the lightest star whose mass is accurately known, though there is little doubt that some others are lighter. However the range of stellar masses is quite small, from about a fifteenth of the sun's mass to four hundred times. Nothing lighter can, apparently, produce enough heat to shine, while anything heavier would develop so much heat as to burst. This is a surprisingly small range, of only about six thousand fold. It may be compared with the range of sizes even within a single group of animals such as the mammals, where a whale weighs as much as many million mice. The reason for the small range is no doubt that stars are atomic reactors, and the working conditions of an atomic reactor are much more stringent than those of a steam engine, a water mill, or a fish.

The nearest star which we can see which is comparable to the sun in brightness is Eta Cassiopeiae. The constellation Cassiopeia is the very familiar M-shaped formation in the milky way near the north pole star. It never sets for observers in Britain, but is only to be seen clearly in the evening from India in autumn and winter. If you look between the second and third of the five bright stars in order of rising you will see Eta. It is about five and a half parsecs away, and is a little hotter than the sun but not quite so luminous, as its mass and area are smaller. It has a companion which is a good deal lighter, cooler, and dimmer, but bright enough to be easily studied. The two revolve round one another with a period which is supposed to be 526 years, though I suspect a few years may be added or substracted when we have studied the system for another century or so.

If there are planets moving round the heavier star with a period of a year or so, then during half the year their inhabitants must see the companion star at night, giving them a good deal more light than our moon, but hardly any perceptible heat. It must move very slowly against the background of "fixed" stars. Perhaps there are rational beings on one of these planets who live long enough to see it make a whole circle, as for example our planet Saturn, or Sone, makes one every twenty-nine and a half years. Perhaps they merely tell one another stories of people in the past who lived long enough to do so.

In the present state of astronomical theory we cannot state with any confidence whether planetary systems like our own are common or rare. But most astronomers guess that they are not very rare, and Eta Cassiopeiae is one of the ten or so visible stars from which the light reaching us tonight started in my lifetime which is like enough to the sun, and otherwise qualified, to have planets which are possible abodes of life. Among the disqualifications is a companion star close enough to disturb the orbits of the planets. This, for example, probably rules out Procyon as a likely sun round which habitable planets may revolve. Of course it may turn out that even when a planet has the correct temperature, the proper chemical conditions for life are usually lacking. It may be that it only originates under quite unusual conditions, or that only very rarely does life beseem into mind, even of the rather poor quality found in most of our species. However unless there are unexpected difficulties, I think there must be many planets in our galaxy whose inhabitants are far superior to ourselves both intellectually and morally.

We ought, however, I suppose, to consider one other possibility. It may be a law of nature that whenever conscious beings discover the sources of energy which would enable them to journey from one planet to another, they use them to destroy themselves.

The constellation which in India is called the Saptarshi, in Britain the Plough or Great Bear, in America the Big Dipper, is now at its highest above the horizon in India soon after sunset. The seven main stars form a conspicuous group, and the middle five belong to an open, moving, cluster of stars. All seven are approaching us at about the same speed of eleven kilometres per second, a quite moderate speed for stars, being about a third of the earth's speed round the sun. The five middle ones also appear to be moving eastward in nearly the same directions. They are also at about the same distance of 24 parsecs, that is to say the light from them started less than a century ago. The last of the seven, which does not belong to the cluster, is about three times as far away.

The two end stars of the seven are approaching us at about the same speed as the rest but their sideways motion is nearly in the opposite direction. All the stars concerned have moved something like a degree in the last thirty or forty thousand years. The shape of the constellation has hardly changed during human history, but it has changed appreciably since men made the first pictures and sculptures. So there is a chance that a representation of these stars, forming a shape different from its present one, may be discovered. The constellation will continue to increase in apparent size for many thousands of years, and then get smaller again until, some millions of years hence, it will be a compact cluster of five stars like the Pleiades, finally crossing the equator to disappear near Capricorn or Makar.

About a hundred fainter stars in the same direction are moving parallel with the central five rishis. None of them are very heavy or hot, like the huge and distant stars which outline the constellation of Orion. A number of the fainter stars in the cluster are not unlike our own sun, but the five conspicuous stars are mostly double or triple systems with at least one member hotter than the sun. Arundati, by the way, is not physically attached to Zeta of the Great Bear, though this is a triple star in its own right.

The Ursa Major cluster, as it is called, is the nearest of a number of open clusters, and therefore harder to study than moderately distant ones like the Pleiades or very distant ones like Khi Persei which to the naked eye appears as a single star. For most of the stars in the constellation do not belong to the cluster but are a great deal further off, whereas, although there are some background stars behind the Pleiades, the task of picking them out is much easier.

It is generally thought that a cluster of stars is generated by the collapse of a nebula, which is a cloud of very diffuse gas and dust, under its own gravitation. If a cloud of collapsing gas is large enough, it will heat up so much as a result of the energy liberated by the fall that reactions between atomic nuclei become possible, and heat and light are then generated by the fusion of hydrogen nuclei to form heavier elements, so a star starts shining. In some nebulae condensations have been photographed, particularly by the Mexican astronomer Haro, which are thought to be the early stages of star formation.

However Ambarzumian, the eminent Soviet astronomer, is more cautious. He admits that nebulae are generally associated with star formation, but it does not follow that stars are formed from nebulae. In the same way large factories are generally associated with extremely rich men, and it was long believed that they could only be built where rich men were able to accumulate large amounts of money. The experience of the Soviet Union, and of our own public sector, shows that this is not so.

The question may only be decided when the nebular concentrations have been watched for a few thousand years. Unfortunately no nebula is anything like as near to us as the Ursa major cluster, so powerful telescopes are needed. It may be settled by theoretical work. Or it may be settled by observations from a sputnik. For recent American work has opened up new possibilities. Some of the rockets which have been sent up above most of the air, and particularly above the layers where ultra-violet radiation is absorbed, have been equipped for photography using very short wave lengths. The results as to the sun's output of ultra-violet radiation of various wave lengths (which would have different colours if we could see them) are not unexpected. But Kuperian, Boggers, and Milligan reported utterly unexpected findings about the night sky. The photograph obtained was very crude. The resolution was only three degrees. Such a camera, using ordinary light, would barely distinguish two objects a foot apart and twenty feet away.

So the photographs parachuted back to earth only showed patches of ultraviolet emission. As expected there was a big patch in Orion, and there were other patches further south along the milky way, some probably due to the few very hot stars which are now visible in the south in southern India about sunset.

But there were also three regions far from the milky way, and not associated with any stars previously thought to emit ultra-violet radiation. One is in the Lion, one near the last of the seven rishis, and the largest of all round Chitra or Spica, the brightest star in Kanya or Virgo. This has a diameter of about 22 degrees, one quarter of the angle between zenith and horizon. Presumably it is a cloud of very tenuous glowing gas. But we do not know whether it has any physical connexion with Spica, which is a fairly ordinary star, a bit hotter and heavier than the sun, but in no way exceptional.

As soon as we can get photographs of greater accuracy at different wave lengths we shall know a lot. For the moment we do not even know what sort of gas is emitting the radiation or how far away it is. Once a sputnik is equipped with instruments for measuring the approximate intensity of ultra-violet radiation coming from different directions, and signalling it back, our views on the distribution of matter in our neighbourhood (by which I mean the region whence light can reach us in a thousand years or so) may be very greatly altered. We already know, from radio reception, of huge clouds of hydrogen in the milky way. We may find that there is a lot more gas between the stars than astronomers think likely at present. If so, they may have to revise their present ideas about the formation of stars.

When a cluster is formed it may fly apart at once, and some clusters have been detected doing so in the last few years, particularly by Blauw in Holland, and by Ambarzumian. If it does not fly apart, most of its members will be held together by their mutual gravitation. However such an association is not stable like a double star or a planetary system. A pair of stars sometimes approach one another fairly closely, though actual collisions must be very rare. Still, as the result of a series of such encounters, any star may acquire enough speed to shoot out of the cluster. Shelley wrote of

"The maze
of planets struggling fierce towards heaven's free wilderness".

The struggle of the planets appears to be hopeless. However Chandrasekhar has calculated how long it should take for a cluster to lose half its members by this method. Applied to the Ursa Major cluster his method gives about two hundred million years. But this is perhaps a bit too long. For the lighter stars have a better chance of escaping, and we certainly have not yet catalogued them all.

In the south soon after sunset we see Trisanku (Crux) followed by Beta and Alpha Centauri, the latter being the third brightest star in the sky. It is bright because it is the nearest star to us, being only 1·32 parsecs away. It consists of three, or possibly four members. Two are of about the sun's mass.

One of these is about twenty per cent more luminous than the sun, the other about half as luminous. They go round their centre of gravity once in eighty years, which is almost the period of Uranus round our sun. The third is a very faint red star which is nearer to us than the main pair. It is about sixteen thousand times as far from them as our earth from the sun, and must go round them in something between one and two million years. Stars in clusters are often much closer than this, and there is no sharp line between a multiple star such as 61 Cygni, another of our neighbours, which has five components, and a small cluster. Men classify. Nature bridges the gaps between man's classes.

JYESTHA

This month is called Jaiṣṭha, because during it the full moon is near to the star Jyeṣṭha in the constellation Brischik, or, in European terminology, to Antares, or Alpha Scorpii. Jaiṣṭha is a much better name than June, because it refers to an observable fact, as do all the other Sanskrit month names. A few thousand years ago Indians were very keen observers of nature. What is more, when the Ṛishi Visvāmitra gave the Gayatri Mantra to the world, he made it clear that those who recite it have the duty not merely to admire the divine glory of Earth, Air, and Sky, but to think about them. If everyone who repeats this mantra would observe and think, India would to-day be leading the world in natural science, as it sometimes did in the past. Similarly if Christians forgave their debtors, as they promise to do in one version of the Lord's Prayer, they would have all the benefits of communism without its disadvantages. I sometimes think that the formulae of the great religions are directed to remedy the prevailing faults of those who practice them. They do not do so very efficiently.

Jyeṣṭha is the brightest of the row of stars which vaguely resemble the body of a scorpion. It is the fifteenth brightest star in the sky. While some of the constellations are not natural systems, but merely groups of stars which happen to be in nearly the same direction, other star groups are not only in the same direction, but at much the same distance. What is more they are moving nearly parallel to one another, so they formed a group a million years ago, and will still be a group a million years hence. Such stars are called a cluster. The easiest feature of two stars to compare is what is called their proper motion. This means the angle through which they move per year, against the background of faint and distant stars. According to the best data available seven years ago, Jyeṣṭha was moving through 32 thousandths of a second each year, in a direction 12 degrees west of south, while Shaula, the star which represents the scorpion's sting, was moving due south through 36 thousandths of a second. These figures will probably be known much more accurately when careful observations have been made for another century. From a human point of view this is a very slow motion. Jyeṣṭha will only seem to have moved through an angle equal to the moon's diameter after sixty thousand years.

One can also find the speed with which a star is moving towards the sun or away from it by careful measurement of the wave length of the lines in its spectrum. These are displaced towards the violet if the star is approaching us, and towards the red if it is going away. Shaula does not seem to be changing its distance, and Jyeṣṭha seems to be approaching at a rate of 3 kilometres per second. This is a small speed compared, say, with that of Rohiṇi (Aldebaran) which is increasing its distance from us by 54 kilometres per second. No doubt Jyeṣṭha and Shaula are not moving at quite the same speeds or directions, but the differences may partly be due to error, and partly to the fact that there really are motions inside a cluster.

The distances of the nearer stars are measured by a simple principle. We know the size of the earth's orbit in several different ways. One is by measuring the time taken for a radio signal to be reflected back from Sukra (Venus). The most accurate, till recently, was the blink principle, or parallax, as it is called. If we photograph Mangal (Mars) at the same time from Greenwich and Kodaikanal it will be in a slightly different place against the background of distant stars. The reason is the same as that for which a near object, say a chair in my room, seems to move relative to more distant ones, such as the far wall, when I look at it with my two eyes in turn. We know the distance from Kodaikanal to Greenwich, so we can calculate the distance of Mangal, and hence the diameter of the earth's orbit round the sun. Next instead of two observations on earth, we photograph Jyesṭha from the earth in March and September. The two "eyes" are three hundred million kilometres apart. But even so Jyesṭha only seems to have moved through 16 thousandths of a second in six months. Some of the other members of the cluster move through over 20 thousandths of a second, others are further off, and have smaller parallax. Seven years ago a hundred and ten stars in the constellations Scorpius and Centaurus had been assigned to this cluster. The number is now probably a bit larger.

The parallax of all the bright stars has been measured, though some are too far away to give any definite result. Astronomers are constantly searching for fainter stars close to us with what is called the blink microscope. Two photographs are taken at an interval of six months, and arranged so that the images of most stars coincide. When looked at in rapid succession the images of near stars seem to move. The parallax of 8 thousandths of a second means that light takes about four centuries to reach us from Jyesṭha, having started in the time of Akbar and Elizabeth I.

Until the nineteenth century no one knew of what the stars were composed. Many philosophers, both in Europe and India, thought they were made of a different sort of matter, or prakṛiti, to that found on our earth. Then when spectral lines were identified with those observed on earth, it became clear that they were made of the same elements as are found here, but extremely hot, in fact consisting not merely of gas but of ionized gas. As a solid, such as iron, is heated up, it first begins to glow with red light, and becomes yellow, white, and blue as the temperature rises. The surface of blue stars is also hotter than that of red ones. Jyesṭha is a red star. Its Greek name Antares means "like Mars", which is also red, for a different reason. It is in fact the reddest among the hundred brightest stars, except for Ardhra (Betelgeuze) in Mrigasira (Kalpurush or Orion). This means that its surface, or more accurately the layer from which most of its light starts, is relatively cool. It was Meghnad Saha, of Calcutta, who first showed how to measure the temperatures of stars from their spectra. The surface temperature of Jyeṣtha seems to be about three thousand degrees centigrade, as compared with nearly six thousand for the sun, and forty thousand for very hot stars such as those forming Orion's belt.

When we know how far off a star is we can calculate its absolute luminosity, that is to say how much light it produces per second. If for example Jyeṣtha were as near as our closest neighbour, Alpha Centauri, which one can see in the south at present, it would be of nine thousand times its present brightness, much brighter than Sukra, but not so bright as the moon even in her first or last quarter. Now most red stars are very dim indeed, too dim to be seen without a telescope even when quite close to us. In fact Jyeṣtha is a hundred thousand times more luminous than the vast majority of red stars. There are no red stars in the intermediate range, whereas the gap between bright and faint yellow stars is much smaller, and there is no gap for the very blue stars.

We can measure the mass of a star when it is one of a pair revolving round their common centre of gravity. Many of the small red stars are double, so their masses are known, and are generally about a third of that of the sun. Jyeṣtha is a double ; but its companion is about 600 times as far from it as the earth from the sun, so its rate of movement has not yet been measured. However for other reasons we think Jyeṣtha is about sixteen times as massive as the sun. As it is cooler, each square centimetre of its surface is much less bright than the same area of the sun. But its surface is enormously greater, so it gives several thousand times as much light. In fact its average density is less than a millionth of that of the sun, and its bulk is so great that if it replaced the sun it would probably extend beyond the earth's orbit. However its centre is almost certainly denser and hotter than that of the sun. The layer from which the light reaches us is almost empty, in fact by human standards nearly a vacuum. Outside it is a layer millions of miles deep in which not only atoms exist, as in the luminous layer, but also molecules built of two or more atoms. These stop light in a much more complicated way than atoms, and give rise to what are called band spectra. The molecule which produces the most striking change in the colour of the light from Jyeṣṭha coming up through it is titanium monoxide.

All along the milky way there are nebulae which consist of clouds of gas and dust. There seem to be three main types, dark nebulae which blot out the stars behind them, reflecting nebulae, in which starlight is reflected from dust, and emission nebulae, whose gases glow with visible light when excited by ultraviolet radiation from stars. Some of the dark ones appear to be condensing into clusters of stars. But we may have to wait some centuries before we know whether the "globules" seen in some of them, which are much larger than our solar system, do in fact collapse under their own gravitation to form stars. This is however how stars are now thought to originate. Their masses are mostly less than the sun's, and Jyeṣṭha is unusually massive. As the matter, which is mainly hydrogen, falls inwards it heats up until nuclear reactions can begin. The rate at which energy is liberated increases roughly with the cube of the mass. Jyeṣṭha probably started its career not much over thirty million years ago as a "super-giant" blue star about ten thousand times as bright as the sun, and thus used up its hydrogen, which was mostly converted into helium, a thousand times as fast. When the hydrogen was largely exhausted the centre got hotter, and it began to convert helium into heavier elements. The whole star expanded enormously. Whereas Shaula is only about eight times as massive as the sun, and has only about eight times its radius. It is believed that it will swell up and redden later. Possibly Jyeṣṭha will swell still further, but it is not likely to get much brighter. It may become a variable with a period of several years. It may then contract again and get whiter, with a shorter period. But at some stage it appears quite likely to explode. If it does so it will be visible by daylight for several days, if any men are left on earth to see it. Perhaps the "life" of such a massive star, from formation to explosion, is a matter of fifty million years or so. Whereas our sun seems to be about four thousand million years old, and may last very much longer.

Such predictions are based partly on calculations made with electronic computers on the basis of physical measurements made in laboratories on earth, and partly on statistics as to the numbers of stars of various kinds found in different clusters. But the mathematicians are much more confident about the evolution of ordinary stars like the sun than about very heavy ones.

The cluster of which Jyeṣṭha is the brightest member is moving relative to the sun. If a flock of birds flies in a straight line and keeps together, it will gradually appear smaller and smaller, and finally seem to contract to a point. The Scorpius-Centaurus cluster will apparently move right across the southern sky to the constellation Puppis, south of Canis major. But on its journey it will lose some members which have developed high enough speeds from approaches to other stars to escape from the gravitation of these neighbours. This is much more likely to happen to light than heavy stars, and Jyeṣṭha will probably stay in the cluster till it explodes.

I am quite aware that some of what I have written is speculative. In particular the past and future of stars and star clusters is based on calculation and not on observation. However there are several different methods of determining their distances, speeds, and sizes which agree remarkably well. I am not an astronomer, but till I came to India I tried to keep up with astronomy. Now I am some years out of date. But the subject still fascinates me. This article was largely taken from Allen's "Astrophysical Quantities", which, along with the poems of Virgil, Milton, and Blake, is one of my favourite bedside books.

I have just been reading Professor Sadhan Kumar Ghosh's "My English Journey". It has, I am told, been criticized. I think its English style, with its curious mingling of classical diction and modernisms such as "gimmick", is admirable, and that many native English writers could learn from him. Although I naturally disagree with some of his estimates of English people and institutions, I think none of them is unfair. His worst misjudgement is, I believe, his statement on page 112 that "Camus, Sartre, and Beckett arouse a shudder of horrified pity for the whole of humanity". On the contrary, I think Sartre is the one living author who can depict "plain heroic magnitude of mind". Goetz and Canoris, the leading character of "Morts sans sepulture", in my opinion the greatest drama of this century, are real heroes. No doubt they came to violent and painful ends. But I am proud to belong to the same species as Canoris.

On page 35 Professor Ghosh quotes from a translation of a poem in the Greek anthology attributed to the great astronomer Ptolemaios (or Ptolemy). A somewhat more accurate, if less poetic, translation than his own runs as follows :

"I know that I am mortal and ephemeral, but whenever I am tracking out, according to reason, the back and forth spiral tracks of the stars, I no longer touch the earth with my feet, but am fed by Zeus himself with god-nourishing ambrosia".

"Ambrosia" is the same word as amrit. Zeus had most of the attributes of Indra. Two different Greek texts give slightly different versions of the astronomer's mental process. The tracks of the planets in relation to the "fixed" stars are, of course, spirals. I do not hesitate to say that this poem and the Gayatri Mantra each help me to understand the other. Ptolemy's poem is a good description of the feelings which I get several times a year when I or one of my colleagues make a scientific discovery of a really unexpected kind.

Professor Ghosh quotes the first and last phrases of this poem. He omits any reference to astronomy. If the emotions of the last phrase had been aroused by a woman, and the Professor had omitted the fact, I might have used a rude word like "castration". If the poem had been inspired by a deity I could have written about atheistic bias, and so on. But if a poet is inspired by scientific research, this is a fact to be suppressed by Professors of Literature. To quote Professor Ghosh's page 82, "One of the saddest things in the English Universities to-day is the emergence of the Literary Specialist". It is sad in India as well.

Visvāmitra was a great poet. Very likely he experienced the Gayatri Mantra as a revelation. This is the usual experience of scientists who arrive at new theories. They certainly do not produce them consciously, and the process feels like a discovery rather than an invention. Visvāmitra, I suspect, was also an astronomer. I do not believe that he created new constellations such as Trisanku. I think it very likely that, after travelling south, he described them to people in northern India who had never seen them. I should like to see a revival, in modern India, of the emotions which, I believe, animated him. This is why I have written this article.

In my last article on stars I wrote about Sirius, the brightest star in the sky, and one of the nearest. Since I did so this star has been very much in the news. A British and an Australian radio expert, Hanbury Brown and Twiss, have revolutionized one side of astronomical technique. Without any giant telescope, and indeed without any optical apparatus but two second-hand searchlight mirrors left over from the last war, they have succeeded in measuring the diameter of Sirius. Their apparatus included a lot of electronic components, but these are available in India. The principle employed was that of interference. It has long been known that when light from the same source shines through two fine parallel cracks very close together and then falls on a screen we do not merely see two white lines. If the light is monochromatic, that is to say all of the same colour and wave length, we get a series of parallel light and dark bands. The paths from the source to the centre of a light band differ by a whole number of wave lengths, so that waves coming through the two cracks reinforce one another. The paths to the centre of a dark band differ by a whole number of wave lengths plus a half, so that the wave from one crack tends to pull electrons in one direction, that from the other in the opposite direction, and they cancel out.

The precise pattern of interference bands depends on the wave length of light, the width of the cracks, and their distance apart. The principle can be used to measure the diameter of a star. Because the star is not a point the pattern differs from that which would be obtained if it were one. The principle of interference was used by Michelson and Pease about thirty years ago to measure the diameter of a few very large red stars like Betelgenze, the bright red star in Orion. But their apparatus was very expensive, and could only be used on a few stars.

Twiss, who works in Australia, proposes to use the new apparatus on the star called Suhail el Muhlif, or Gamma Velorum, which is one of the most interesting stars in the sky. At present* Canopus, Agastya, or Alpha Carinae, is conspicuous in the south about sunset. This is a very distant star, but produces so much light that it is the second brightest of all stars in the sky, even though if the sun were removed to the same distance we should not be able to see it with the naked eye. About an hour and forty minutes after Canopus two fairly bright stars reach the southern meridian. These are Gamma Velorum and Zeta Puppis almost due north of it. These are the two hottest stars which appear bright enough to be easily recognised. More accurately Gamma Velorum is a double star consisting of two components moving round their common centre of gravity of which the hotter and brighter is what is called a Wolf-Rayet star (after the names of two astronomers). Wolf-Rayet stars show a continuous spectrum, corresponding to a surface temperature of about eighty thousand degrees, and also bright lines. In fact their spectrum is superficially like that of a gas discharge lamp with a fluorescent background.

Most astronomers think that the continuous spectrum comes from the surface of the star, and the bright lines from an atmosphere surrounding it. The new technique will enable astronomers to mesure separately the diameter of the star itself and of the atmosphere round it which may be ten times greater. As Gamma Velorum appears overhead in Australia, Twiss is probably measuring it now. But as the new techniques can be applied to any stars bright enough to be seen, there are plenty of opportunities for Indian astronomers or physicists to use

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* March, 1959.

them on other stars without spending much foreign exchange.*

The stars with very hot surfaces are believed to be relatively young. In a few cases where several type O stars like Zeta Puppis are moving away from a common centre, we can calculate the date of their origin, at which they started from it. Some of the stars in Trisanku, or the Southern Cross, which is conspicuous about midnight at present, are also pretty hot, and must be fairly new. Now according to Indian tradition, the great rishi Visvamitra made several southern constellations, including Trisanku. I find Visvamitra, who had considerable difficulty in controlling his passions, a good deal more sympathetic than many men of a holier disposition who found the path to enlightenment easier. But I am afraid I don't believe he created new star systems. I want to suggest that he may quite possibly have noticed the appearance of new stars in the southern sky, and pointed them out to his contemporaries. If so the legend might easily arise that he had created them, especially if they increased in brightness for some years after their first detection. We know much too little about stellar evolution to say with certainty that this is possible or impossible. Whereas we can say that, for example, the Seven Rishis are many millions of years old, and were shining long before there were human beings. I hope to write about them in a later article.

I want to draw the moral that Indian scientists would not complain so much about lack of equipment if they would keep their eyes open for cheap methods invented in other countries. It is of course still better to invent cheap but efficient apparatus oneself, as J. C. Bose, for example, did. I have just induced the Indian Statistical Institute to offer a post to a colleague who has done this. Personally I try not to use apparatus at all, and to get my junior colleagues to work with as little as possible. One reason for this is a moral one. The use of complicated

* In the three years since this was written, I have heard of no evidence that they have done so.

apparatus separates scientists who use it from ordinary men who use such simple machines as ploughs and potters' wheels. There is in fact a very great deal to be found out about such machines. In particular what are the best designs for a plough to be used in the various types of soil found in different parts of India ? I am pretty sure that most of the existing kinds demand a bit more work from a bullock than is absolutely necessary. I think the physics of ploughing is more important for India than some of the branches of physics which are being investigated in our university laboratories, and quite as interesting scientifically. I am not a consistent Gandhian, but I certainly think that Indian scientific research would be the better for adopting a few Gandhian principles, one of which is to regard machine as made to serve men, and never to think of men as made to serve machines.

CLASSICS

By classics I mean documents in languages no longer used by all members of a population, documents which are judged by many to be worth reading for their own sake, and not merely because they serve to determine a historical fact. I say "by all members of a population" because Latin is certainly used conversationally in Roman catholic institutions, and it may well be that in some *Math* the holy men ask for their food in Sanskrit.

I would be inclined to expand this definition and say "documents which are, at least in part, worth learning by heart for reasons other than the conciliation of supernatural beings".

You may ask who is Prof. Haldane to speak on such a matter. I notice that in India a new caste system is developing before the old one has disappeared. The new system is based on academic degrees. One cannot teach Bengali, chemistry, history, or what you will, without a degree in that subject. And a higher degree given for research is almost obligatory if one hopes for a professorial chair. It is only a question of time before I am debarred from teaching science or statistics, since I have no degree of any kind in these subjects. But in terms of the new caste system, I am qualified to teach the classics, since I secured a somewhat marginal first class in *Litterae Humaniores*, vulgarly called "Greats" at Oxford. However as I have no higher degree my qualifications are slight.

In fact I have been forgetting Latin and Greek for a little over 44 years, and have forgotten even more Greek than Latin, which is a pity, as Greek literature is far finer than Latin. Nevertheless I remember enough Greek to be able to add a few lines annually to my small store of remembered Greek verse.

As I shall demonstrate later, I know nothing of the ancient literatures of India. But I want to suggest that an educated Indian, no matter what the profession by which he earns his living, might reasonably be expected to know enough Sanskrit to read a little fresh literature, and memorize at least a few new slokas, each year. I can only justify this advice by reference to my own experience, and I must therefore ask you to excuse what you may well regard as my egocentric attitude.

One elementary point must be made. The amount of Sanskrit literature available is vastly greater than that of ancient Greek, or pre-christian Latin literature. I doubt if it is larger than the whole volume of Latin literature, largely post-classical, which includes such documents as Magna Carta, St. Thomas Aquiras' Summa Thelogica, and Newton's Principia. But this volume imposes a great burden on scholars, and many, I fear, have sunk under it, becoming mere repositories of learning. We have such dry-as-dust scholars in Europe, and they were common a century ago. They were so preoccupied with the past that they knew little of the present, and what they did they despised or hated. I dare say that many pandits conform to this pattern. Please do not think that I despise it. It seems to me much more laudable to accumulate a knowledge of what various people have written about the story of Nala and Damayanti than to accumulate a large bank balance or a collection of third-rate European art, as some rich Indians have done. If by the way any one here is an expert on this story I should like him to explain how the science of dice is relevant to counting leaves on a tree—or rather, since I know how it is relevant, how Vyasa thought that it was so.

Such people, however, seem to me to be prematurely old. They show little sign of having lived in the present, but behave like ghosts from the past. My excuse for reading the classics is that they rejuvenate me. The great and original classical authors

—who were few compared with the more derivative ones, saw the world and their own emotions with a freshness which we cannot hope to emulate. Who today can write on the origin of the world with the simplicity of the Vedic hymnologist who concluded by saying "This creation, whence it arises, whether it was made or not,—he who watches over it from the highest heaven knows—or perhaps he does not know" (Rik X, 1291). We have read too much philosophy, theology, and science, but perhaps we are not much nearer the answer. Who can now look into his heart and write as simply as Catullus

"Odi et amo, quare id faciam fortass'a requires.
Nescio, sed fieri sentio et excrucior".

"I hate and love. You may ask why I do so. I do not know, but I feel it happening, and am tortured", or Aiskhylos who represented the conscience and the reason of the same man as deities contending for him. We have read Dostoievski and Freud, (or more probably translations of their works). We think that we can answer Catullus' question, or restate Aiskhylos' theology in terms of ego and Superego. This may be a little nearer to the truth, but we shall certainly gain if we can state our problems in simple language as well as in sophisticated terminology. Perhaps Catullus may help us to understand how ordinary people feel.

For me the early formulations of scientific hypotheses are especially fascinating, most fascinating of all when they are formulated by a poet. What do we mean, for example by a "law of nature" ? Perhaps a statement about how matter behaves, which we take to be true in all places and at all times. Now let me go to our ancient Greek sage Empedokles, a poet and philosopher who lived in Sicily 2400 years ago, and see how he put it. I accept one emendation of the text which has come down to 70. "There is an oracle of necessity, an ancient vote of the gods, everlasting, sealed down by flat oaths." This is how things behave now, and always will, but before the gods reached their decision they may have behaved otherwise. Perhaps this may be nearer the truth than the usual scientific doctrine. Perhaps in the past, matter, or mind, or whatever we call that which had being, was wilder than today. It has organized itself into particles, waves, feelings, emotions, and so on. It has evolved, as plants and animals did, but far more slowly. We need not suppose that the gods held up their right hands or dropped white pebbles into a box. But perhaps physics as we know it is the result of a process of organization.

Among other things I read the classics for mythology. The mythology of the monotheistic religions is far poorer than that of the polytheistic, and in India mythology has perhaps suffered from the attempts of earnest men during over 2000 years to moralise it. The Greco-Roman myths are familiar to you, if only from their reflexions in the poetry of Keats and Shelly. I take two examples from other European mythologies. One is the prophecy of the Sputnik in the Volospa, a prophetic book in classical Icelandic, which I should put third on my list of classical European languages, a long way after Greek and Latin. I rely on memory, and have doubtless got a word or two wrong. "Eastward in Ironwood lives the old Witch, and rears Fenri's children there. Among them all one shall be born, the ogreshaped moon-thrower". "Tungls tiugari" is generally rendered "who shall pitch the moon down". But I think the words mean what I said. Perhaps the *raksasa* in question is going to throw a moon up. Fenri is the supernatural wolf who will take the world in his teeth on the day of doom, and eat the supreme deity Odhinn, only to be killed by Vidhar. Ironwood lies east of Sweden. History is beginning to catch up with mythology.

Indian mythology is full of impossible exaggerations, such as stories of heroes who killed an *aksauhine* in one day. But if we must have exaggerations, I prefer the account of Clust Mab Clustfeinad in the tale of Kulhwch and Oliwen in the ancient Welsh book called the Mabinogion. He was one of King Arthur's court, and his hearing was so good that "though he were buried 7 cubits deep in the earth, fifty miles off he would hear the ant in the morning when it started from its nest". However his auditory acuity was perhaps surpassed by the olfactory prowess of Ol Mab Oliwydd. "Seven years before his birth were his fathers swine stolen, and when he attained to manhood he tracked the swine and came home with them in seven herds". The translation, by the way, is by men who think in Welsh and have preserved the form of the Welsh sentences.

Mythology is good for the mind if you imagine it and do not believe it. It is in my opinion very bad if you believe it to conceal deep truths. Our ancestors had the good fortune to be able to tell highly imaginative stories about the universe, as we now tell them about human individuals. Good science fiction is our nearest substitute for mythology.

Now while I know a little Greek and Latin, I cannot really follow classical Icelandic, and am wholly ignorant of classical Welsh. I must rely on translations, as unfortunately I must for Sanskrit. I am quite aware that the greatest poetry and the greatest prose are untranslatable. This is true, but misleading. I shall return to it later. Meanwhile I remark that there are translatable poets. Byron appears to be the most translatable of the English poets. Bhartṛhari of the Sanskrit poets. He goes particularly well into French. Neither is negligible as a poet. But if we have read great poetry in very pedestrian translations, as I did for example with Virgil's Aeneid at school, and have later learned to appreciate it in the original, we may be able, however dimly, to sense the original even behind a translation as appalling as Pratap Chandra Roy's of the Mahabharata into English.

Let us examine a little more closely the statement that the greatest poetry is untranslatable.

This does not mean that all translations are equally bad. In the first place much is gained by translation into a suitable language, whose grammar at least resembles that of the classic in question. I have read, or at least dipped into a number of translations of the Bhagavadgita. Of these Schlegel's translation into Latin strikes me as incomparably the best, even though Schlegel used words like "*dumtaxat*," which is characteristic of the prose of Cicero, but which poets rightly avoided. But, to take a trivial example, in Latin we used *que* at the end of a word where modern European languages use "and", *und, et, y,* and so on before it. Thus *mrtasyaca* is rendered as *mortuisque*, and so on. It seems to me probable that the ideal modern language into which to translate Sanskrit may be Russian which is very rich in inflexions. I think that Bengali poetry would go better into German or French than into English ; into German because of the similarity of the word order, into French because for example one can use *aller* as *jana* is used in Hindi and similar words in other modern Indian languages.

The second point is more interesting. It is possible that great poetry may be translated into great poetry if the emotions of the translator are like enough to those of the author, even if his treatment is utterly different. Thus the Psalms of David, composed in Hebrew nearly 3000 years ago, have been done into Greek, Latin, and all the later European languages by men who, if they were not often poets, at least had a deep religious feeling. Even when they mistranslated the original, they were writing poetry, or something near it. For example in the English prayer book we read of Joseph in an Egyptian prison "Whose feet they hurt in the stocks ; the iron entered into his soul". This is translated from the Latin version. A more correct rendering, in the Bible, is "Whose feet they hurt with fetters; he was laid in iron". But in my opinion "The iron entered into his soul" is poetry, due to St. Jerome. We have a number of English translations of Homer's ancient Greek epics. It is quite possible that Alexander Pope's is the best. But it is certainly a very long way from the original. Homer was titanic, Pope was elegant.

However even if a translation is better poetry than the original, it is no substitute for it. Yet I see no harm in studying the classics, especially the more sophisticated poetry, with the aid of a translation. In fact I am afraid that I find much Greek verse very difficult without it. At the moment of writing I am suffering from having no "crib" of Pindar. Still more is this true of the classical Italian of Dante Alighieri, a language which I have never formally learned. I class Dante unhesitatingly with the classics, though he only wrote seven centuries ago. If he was the first great poet to write in anything of all near to a modern European language, he was, in another sense, the last of the Greco-norman classical authors. The early Christians had overthrown the ancient religion as ruthlessly as the Muslims stamped out the ancient religion of Iran and tried to stamp out that of India. Dante identified Iuppiter with the Christian God. This enabled him to place sincere and pious pagans in the Christian heaven, and those who had offended against Iuppiter in the Christian hell, notably the unfortunate Capaneus, who might have hoped for release when the ancient deities were overthrown. Several minor mythological figures of the ancient world, such as Kharon who ferried the souls of the dead across the river Acheron, and Minos who pronounced judgement on them, found employment in hell. Those of you who have been to Rome will remember the figure of Kharo in Michelangelo Buonarotti's great cosmological fresco in the Capella Sistina, Dante did not hesitate to add to Greco-Roman mythology ; and his account of the last voyage of the hero Ulisse, or Odysseus, which appears to be entirely his own invention, is possibly the greatest passage in European literature. He did not conceal his debt to ancient Latin poets, particularly Virgil and Statius. He did conceal the fact, which was only discovered in this century, that much of his cosmology was taken directly from an Arabic poem on the night journey of Muhammad. I believe that he would have rejoiced to know that his debt to Islam, which might have cost him his life had it been discovered during the crusades, when he wrote, would be made manifest after his death. If he could not bridge the cultural gap between Islam and Christianity he played a vital part in the revival of the pre-christian culture of southern Europe. But his interests were still more universal. I know of no poet who refers to more different animal species than he. I cannot see an insect flying into a light without remembering his lines "Noi siam vermi. Nate a formar l'angelica farfalla che vola alla giustizia senza scherme". "We are worms born to form the angelic moth which flies to judgement without protection". No student of European culture can ignore the Divina Commedia. There seems to be little doubt that we have an authentic portrait of Dante. On seeing it one can understand why children pointed at him in the street, and said "There is the man who has been in hell".

Pardon this digression. Let us go back to the ancients. Apart from the Vedas, Sanskrit literature begins with your great epics. So does Greek literature with those of Homer, on an altogether smaller scale than yours, but possibly containing less which might be ommitted without serious loss. It is not so generally known that epics continued to be written for more than a thousand years after Homer's poetry was written down, and thus a good deal longer since it was composed. In fact classical Greek literature, apart from a few epigrams composed in Christian Byzantium, ended rather abruptly with an epic, the Dionysiaca of Nonnos written in Egypt soon after A.D. 400, when Christianity had indeed conquered the old religions, but had not yet exterminated them. It is customary to denigrate this epic, which celebrates Dionysos' conquest of India. My own view is that Nonnos' Dionysos probably includes at least echoes of Kṛsna, though it was more usual to equate Kṛsna with Herakles. Until an Indian scholar reads Nonnos in the original we shall not know whether this hypothesis is completely false. Nonnos was not a Homer, but he was, in my opinion, a poet. If I had to choose an inscription for an observatory I should find it hard to better Nonnos' line :

τι πλεον ἠθελες ἀλλο μετ' αἰθερα
καὶ πολυν ἀστρων;

"What else do you desire more than the *akasa* and the vault of stars ?", spoken by Zeus to Dionysos' mother Semele. As you perhaps know, Zeus granted her a boon, as Dasaratha granted one to Kaikeyi. Zeus' wife Hera came down to Thebes in disguise and persuaded Semale to ask the god to show himself to her in the form in which he appeared to the other deities. After using the line in question he was forced to keep his promise, and Semele was burnt up. However according to some poets she was later deified, and Pindar, a far greater poet than Nonnos, sang of her :

ζωει μεν εν ὀλυμπιουσιν
ἀποθανουσα βρομω
κεραυνου τανυεθειρα Σεμελη,
φιλει δε μιν Παλλας αἰευ.

"She lives among the Olympions who died from the blast of the thunderbolt, Semele of the spreading hair, and Pallas always loves her". Pallas was the goddess of wisdom. Perhaps Semele was on her way to becoming the goddess of curiosity, who died to know the truth for one instant, to "perish and understand" as one version of a psalm puts it. Arjuna is said to have survived such a vision. With all deference to Vyasa, I think the story of Semele may be nearer to the truth than his. Another hero who survived seeing the gods as they are was Aeneas. His mother, the goddess Venus, came to his aid as the victorious Greeks were destroying his native city of Troy. He wished to kill Helen, whom he believed to have been responsible for Troy's fall. His Mother explained to him that gods, not men and women were responsible. Then she removed from his eyes for one moment, the mist which veils the vision of mortals and showed him,

> "Hicufi disiectas moles avulsaque saxis
> Saxa vides mixtoque undantem pulvere fumum
> Neptunus muros magnoque emotia tridenti
> Fundamenta quatit, totamque e sedibus urbem Eruit."

"In summas arees Tritonia, respice, Pallas Insedit, nimbo effulgens et gorgone saeva".

"Here, where you see buildings thrown apart, rocks torn from rocks, and billowing smoke mixed with dust, Neptune is shaking the walls and, with his great trident, the foundations, and tearing the whole city from its foundations".

"On the top of the citadel—look behind you,—Tritonian Pallas sits shining with radiance and her awful Gorgon."

For one instant he saw the dire faces of the gods. This passage, and other parts of the second book of Virgil's Aeneid, were one of my principal consolations when London was burning under the German aeroplanes in 1940. Virgil told me that it was idle to blame Mr. Chamberlain or Lord Halifax. Britain was in the grip of the superhuman forces described by the prophet Karl Marx. But I would have you note that Virgil had given the best description that I know of a bomb bursting during an air-raid. He had never seen the rocks torn apart and the clouds of billowing smoke and dust. But he knew the anger of superhuman beings. Nor had Milton seen an aerial battle when he wrote of the vanquished,

> "Hurled headlong flaming from the etherial skie
> With hideous ruin and combustion down".

He also understood something about the world process. Please do not let me leave you with the notion that for me the principal function of the classics is to convince me of the truth of Housman's lives :—

> "What evil luck soever for me remains in store
> 'T is sure much better fellows have fared much
> worse before".

This is no doubt truc, and we can even learn from the classics to bear it while it is happening from such lines as Aeneas' saying

"for sitan haec olim meminissc juvabit"

"Perhaps in future wc shall enjoy *remembering these* happenings."

But we can also learn to enjoy life. The opportunities for enjoyment may be less in India than in Britain, but I am strongly of opinion that Indians do not exploit them to the full, partly no doubt because recent religious developments have made them ashamed of doing so.

If, as I hope you do, you enjoy one of the great and simple pleasures, learn to be open and laugh about it as Catullus did when he wrote to Ipsithilla

"At domi maneas paresque nobis
Novem continues fuctutiones."

"But stay at home, and prepare nine fucks on end for us". If you are a tired sexsualist like Petronius, say so as he did in the lines

"Foeda est in coitu et brevis voluptas :
Non sicut pecudes libidinosi
Caeci protinus irruemus illuc,
Sed sic sic sine fine feriati
Et tecum jaciamus osculantes".

"The pleasure of sexual union is foul and short ; Let us not rush blindly into it like lecherous cattle ; but, on an endless holiday, lie together, kissing thus, thus."

But do not pretend that it is not a fit subject for verse, even if most Latin verse on the subject is more circumlocutory and decorous than that which I have quoted.

The other simple pleasures were also celebrated. Wine, dancing, eating, flowers were praised, all the more intensely because only a few of the poets had any strong belief on a future life whether on this earth or elsewhere.

Though the professional poets celebrated music and poetry, perhaps the greatest eulogy of pure thought is by the great astronomer Ptolemy.

οἶδ' ὅτι θνατὸς ἔφυν καὶ ἐφάμερος,
ἀλλ' ὅταν ἄστρων ἰχνεύω κατὰ νοῦν
ἀμφιδρόμους ἕλικας,
οὐκέτ' ἐπιψαύω γαίας ποσίν,
ἀλλὰ παρ' αὐτῷ Ζηνὶ θεοτρεφέος
πίμπλαμαι ἀμβροσίας.

"I know that I am mortal and ephemeral, but whenever I am tracking according to reason the ascending and descending spirals of the planets, I no longer touch the earth with my feet, but am filled with god-nourishing ambrosia by Zeus himself." This is perfectly correct description of a psychological state with which I am quite familiar. But it is condensed. The phrase which I have translated as "ascending and descending spirals" is literally "both running snails." "I track according to reason" is the best description that I know of scientific research. A scientist must be at once a dog with his nose to the ground, and a god using the purest form of reason. The figure, by the way, is Greek. Sokrates, who had a considerable respect for God, and was therefore killed as an atheist, used, in conversation, to swear playfully "By the dog, the god of the Egyptians" rather than "By Zeus" or "By Apollon". In English we can translate this compactly. "By Dog", and I sometimes use this phrase in homage to the undying memory of Sokrates. Not everyone can make a pun in a language yet unborn.

But to return to the poetry of our ancient authors, they preached the enjoyment of life, but also the duty of abandoning it without hesitation if the moral necessity arose. There are of course innumerable examples of moral precepts based on religion, as in all other literatures. But they also taught a morality wholly independent of religion. I quote two examples. As you know 300 Spartans died at Thermopylae after holding up a Persian army said to have consisted of a million men for a day. Their epitaph is as follows :—

"O stranger, inform the men of Lakedaimon that we lie here, being persuaded by their words". Lakedaimon was the capital city of Sparta. This is the literal translation. There is nothing about the gods, about patriotism, about honour. There is the present passive participle of the verb ϵυν0ω. I persuade, one of the most important and characteristic words in the Greek language. It took a lot to persuade an ancient Greek. But when he was persuaded he was quite prepared to die if necessary. Peitho, or Persuasion, was a goddess. Notice that the participle is in the present tense. The verse does not say that these men were persuaded. It says that they are dead, and are still persuaded. Death has not shaken their decision. They are eternally fixed in their resolve.

This epitaph was not written by a Spartan, but by the poet Simonides from the island of Keos. The Spartans produced very little poetry, but they were susceptible to it. According to legend on one occasion when they had been badly defeated, the oracle of the god Apollon told them to apply to the city of Athens for a man to bring them victory. The Athenians had no great liking for Spurta, but could hardly disobey the god. They sent a lame poet called Tyrtaios. Some of the poems attributed to him survive. They are not great poetry, but they are obviously good songs to sing on a march. According to the story Tyrtaios won the war for the Spartans.

A more detailed exposition of a secular or lay morality opens one of the Odes of the Roman poet Horace

"Iustum et tenaeem propositi virum
Non civium ardor prava jubentium,

Non voltus instantis tyranni
Mente quatit solida, neque Auster
Dur inquieti turbidus Adriae,
Nec fulminantis magna Iovis manus :
Si fractus illabetur orbis
Impavidum ferient ruinae".

Again I give a literal translation. It is ugly because the Latin word order is very different from the English. It can of course be translated into English of a normal character. I keep as close as I can to the Latin because I am vain enough of my culture to think that these lines should be translated into all languages.

"The just man who holds to what he has resolved to do, neither the heat of citizens commanding wicked acts, nor the face of the tyrant standing over him, shakes in his solid mind, nor does the south wind, opaque lord of the unquiet Adriatic, nor the great hand of thundering Jupiter. If the world collapses broken, the ruins will strike him unafraid".

Horace was not an original thinker. He echoed the thoughts and sentiments current around him. This ideal was current in his time. A few men in each generation lived up to it. Most of them died violent deaths. Sometimes a pair, like Marius and Sulla, met in a disastrous civil war. But they explain the rise of the Roman Republic. The ideal is completely courageous, but it is not the *kshattriya* ideal, which is very like our west-European knightly ideal. It is for example incompatible with a hereditary monarchy, which is one reason why I do not propose to go to Delhi next month to meet the Drone of England. (The word drone denotes the husband of a queen bee). It is certainly incompatible with the great monotheisms, probably with any religion.

To find this ideal developed in detail we must read Plutarch's "Lives of the most noble Greeks and Romans". This was written under the Roman Empire when the ideal was no longer practicable. And historical research has shown that there is a large element of fiction in many of the lives. One cannot trust

Plutarch for a detail unless it is confirmed by other evidence. The lives and deaths of his 46 heroes were modified to conform with an ideal. They include one "barbarian", Ardeshir or Artaxerxes, King of Persia.

This book had a great influence at the time. Plutarch was made a consul and viceroy of Greece by the first of a consecutive series (the only such series) of four good Roman emperors.* The influence of Plutarch's Lives in modern Europe began with its translation into French in 1559 and English in 1579. It has, in my opinion, had more effect on European history than any other book from the ancient world except the Bible. There is no doubt that many of the leaders of the English Revolution which began in 1642 and the French Revolution which began in 1789 deliberately modelled themselves on Plutarch's heroes.

I do not know whether the Prime Minister of India has read Plutarch. They probably made him read Horace at Harrow. But I think he conforms more completely to the Horatian and Plutarchian ideal than any other man alive today. It is obvious that if India can produce a series of men with such character, its history in the next few centuries may not be tranquil, but will be a major theme in the story of mankind. For this reason I should like to see Plutarch's lives translated into every Indian language. But this will not be done adequately without at least some knowledge of the ancient languages by their translators.

There were other Greek and Roman ideals, of which the most important perhaps was that of the philosopher, a non-violent person living more or less the life of a brahmin. What is quite certain is that Greek travellers to India described the Brahmins and Sramans as philosophers. It seems likely that in the last 2000 years the Brahmins have become progressively entangled in ritual and formalized learning. I do not know of

* Formally the series begins with Nerva, who only reigned for 16 months. It is not very difficult for a despot to govern well for a year or so, during which he can remedy some of the wrong of his predecessor. It is much harder to continue the process, as many become apparent not a hundred miles from Calcutta. If we count Nerva, there was a series of five good emperors.

any satisfactory delineation of the ideal of a philosopher in verse. You will find one in prose in Plato's "Apology", which is supposed to be Sokrates' defence at his trial and the "Krito" which is an account of his death.

I must apologize for the form of this discourse. It is as if I had shown a party of tourists round a city, pointing out various buildings without regard to historical sequence, and telling such tales about them as happened to come into my head. You will find accounts of the ancient Greco-Roman literature in many textbooks and encyclopaedias. It is not so easy to find adequate accounts of Icelandic and Keltic literature. I have deliberately described our classics from a subjective point of view. The passages which I have quoted are rather diverse, but about half of them agree in causing the hairs on my body to erect like those of an angry dog. I have tried to suggest the ideas and emotions which they generate in a man who cannot by any stretch of the imagination be called a scholar, but who, just for that reason, reads the works of the ancients as their authors intended them to be read, not concentrating his attention on passages which, either through the complication of the author's diction or the corruption of his texts by copyists, are particularly obscure.

Once in my life I have contributed to the better translation of such a passage, in which for at least four centuries, a verb in the middle voice had been translated into Latin and modern Europan languages as if it were active. Only recent biological discoveries made it clear what the author (the philosopher Aristotle or more probably a disciple who wrote under his name) meant. But specially in dealing with poets, we must be extremely careful. Let me give you an example from English literature. A scholar of Austrian birth who is a professor of English in America, gave a lecture in University College London on the English language, especially on the metamorphosis of words. He quoted the degradation of the word sensation to mean surprise, as in the sentence "A great sensation was caused in Calcutta yesterday when the Chief Minister* walked along Central Avenue in a green panjabi and a scarlet dhoti". The lecturer did not know Louis Carrol's remarks on the subject of this word, though I consider that his light verse is part of English literature. The lecturer then pointed out that Chatterton, who wrote bogus old-English poetry in the 18th Century used the word slug-horn, a corruption of the same Gaelic word as slogan, meaning a war-cry, as something which is blown in a battle. This was one of Chatterton's mistakes. He next remarked that the last two lines of one of Browning's strangest poems are

"Dauntless the slughorn to my lips I set,
And blew Childe Roland to the Dark Tower came".

He supposed that Browning had fallen into the same trap. He did not know that "slug-horn" was used in eastern England in the 19th Centnry to mean a deformed horn on an animal. I do. So, I suggest, did Robert Browning, a man of most variegated knowledge. The poem is a description of a bad dream or conceivably of supernatural occurrences. What more suitably hung on the door of a nightmare tower than a deformed horn ? The fact that Chatterton had misused the word and killed himself soon after serves to enhance the nightmare character of the whole poem, and Browning, when he wrote it, may well have laughed in anticipation of the errors of critics yet unborn. You need a very profound knowledge of a language before you can catch a major poet napping.

For this reason I suspect that emendations often throw more light on the pandit than the poet. Thus one of our British pandits recently emended Catullu's lines

"Gallicum Rhenum, horribilesque ultimosque Britannos"
"The Franch Rhine, and the horrible and ultimate
Britons," to
"Callicum Rhenin horribilem gelu, ultimosque Britannos"

* If this would be libel, put "J. B. S Haldane."

"The French Rhine, horrible with frost, and the ultimate Britons".

The critic is prepared to admit that his ancestors lived on the border of the world known to Catullus, but not that they were horrible. That is a fact about the critic. He does not apparently realise that the poem in which these lines occur was intended to be slightly comic, and Catullus might very well have used a phrase which was both grammatically awkward and difficult to pronounce. This, I think, is a fact about Catullus.

I venture, then, to suggest that an unscholarly reader like myself may sometimes see the wood where pandits only see individual trees. I ask you, in reading your own classics, not to bother too much about the precise meaning of words and phrases on which pandits differ.

And I ask you not to be afraid or ashamed to read our European classics in such a format as the Loeb library, where Greek or Latin and English are placed on alternate pages. The Greek alphabet is about as different from the Roman as Bengali from Devanagari, and you should not find it too hard to learn. Even with the aid of a dictionary you will sometimes find it difficult to see how the two versions correspond, particularly in Pindar, Horace, and the choruses of the Athenian dramatists.

I believe that it is proposed to start an Institute of European studies in India, perhaps in Calcutta. I think that such a scheme is most important, if only for the self-respect of Indians. European culture is not the whole of human culture. It is a branch of it, and during the last four centuries it has, I think, been the most important branch. But it is something which may and should be studied from outside, and where outsiders can probably notice facts which have escaped Europeans. One can no more study European culture without some knowledge of Greek and Latin than one can study Indian culture when ignorant of Sanskrit, Pali and classical Tamil. But although I hope this Institute may include a member with a thorough knowledge of Greek and Latin who has devoted his life to their study, I hope that other members may be content with a knowledge as superficial as my own provided they have other complementary knowledge. It is likely that Homer was wholly uninfluenced by Indian literature, and Vyasa and Valmiki by European literature. I have no doubt that Firdausi was influenced both from the East and the West.

May I end this lecture with apologies for its disjointed character and for mistakes in passages which I have quoted from memory, and with the expression of the hope that the Institute of European Studies may be founded before I am either dead, or too old and deaf for me to be able to attend its meetings.

SUMMARY

I begin with an attempted definition of the classics, and a plea that educated men should continue to read them without too much attention to details of scholarship. I read them because they keep my mind young and stimulate my imagination. I give two examples from ancient Scandenavian and Welsh mythology, and one from Greak mythological philosophy. I deal briefly with the problem of translation, including translation from Sanskrit into Latin.

I digress for a moment to propound the heretical view that Dante Alighieri was as much the last of European classical authors as the first modern author.

The rest of the address is a more or less free chain of associated ideas, illustrated from Greek and Roman authors, perhaps comparable to those of Eliot or Pound but I hope more explicable. Beginning with a line of the poet Nonnos on Semele, I consider Pindar's and Virgil's accounts of those who saw the gods. After quoting Catullus and Petronius on sexual pleasure, and Ptolemy on intellectual pleasure, I discuss the ethical ideas of Simonides, Horace, and Plutarch. A further digression on Catullus and Browning illustrates the dangers of

literary criticism. I close by hoping that Indian Institute of European studies may be founded in Calcutta.

It may be that such a disorderly series of free associations may give a better idea of what the Graeco-Roman classics mean to a desultory reader than would a more systematic exposition.

RELATIONS BETWEEN BIOLOGY AND OTHER SCIENCES*

The relation between two sciences should be one of mutual aid. A science advances both when a new question is asked and when it is answered. Thus astronomy advanced when Hipparchus asked "Do the so-called fixed stars change their positions relative to one another", and first catalogued such positions. It was a greater advance when proper motions were detected and measured.

Biologists certainly ask questions of other scientists, such as "Can you make me an instrument to see the detail of objects less than. 001 mm. in diameter ?" "What is the composition of the wax produced by this plant ?" "How many years have elapsed since our ancestors became land animals ?" But workers in other sciences can and should ask questions of biologists. Perhaps the chemists and geologists have the most important questions to ask.

MATHEMATICS

Let us begin with the relation of biology with mathematics, the most abstract of the sciences. Some of the questions which the biologist asks are really questions of physics. For example, in the Proceedings of the Royal Society for 1951 G.I. Taylor discusses the swimming of microscopic flagellate organisms such as many algae, protozoa, and spermatozoa. Here the viscosity of water is its most important property, and the mathematical problem is quite different from those raised by swimming

*The full text of Prof. J. B. S. Haldane's lecture delivered on 2-1-52 at the 39th Session of the Indian Science Congress Association held at Calcutta.

organisms even a centimetre long, let alone ships or aeroplanes. Taylor has only solved the problem in two dimensions,* so there is plenty more to be done.

There are, however, a number of mathematical problems raised by purely biological facts, particularly problems of population. The rate of growth of a population depends on its past. Thus that of a human population depends on the numbers of women at various ages between 15 and 45. Such problems inevitably lead to integral equations. In fact the modern theory of integral equations, and of functionals in general, owes much to Volterra's investigations on fish populations. These have in turn reacted on biology by suggesting biological characters of organisms which should be measured, for example fertility as a function of age. My own investigations in this field have led to some novel solutions of non-linear finite difference equations.

The branch of mathematics which owes most to biology is statistics. The normal or Demoivre-Laplace-Gauss distribution was shown by Quetelet to apply to human height and other biological measurement, and the theory of correlation, so important in economics, was largely developed by Karl Pearson in his investigations on heredity. The benefit has been mutual. Biometry is now an essential part of biology.

Another branch of mathematics which is growing in connection with biology is cybernetics, defined by Wiener as the theory of control and communication in animals and machines. Because this theory has been developed in connection with machines, for example thermostats, it is sometimes thought that an attempt to apply it to men and animals involves the assumption that they too are machines. This is incorrect. An animal may agree with a machine in a mathematically determinable characteristic, for example the rate at which its heat loss increases when its temperature rises ; just as it can agree with the machine in weight, horse power, and so on. We can then legitimately argue from the machine to the animal without equating them.

* He has since given a three dimensional solution.

PHYSICS

To illustrate the interactions of physics and biology, I will mention just two fields of physics, the new subject of nuclear physics and the old one of polarized light. Physicists have now given us a time scale determined by radioactivity, which is long enough for the very slow process of evolution. It is, however, worth mentioning that it was a biologist, Darwin, who first gave nearly the correct time scale for geological events. In the first edition of "The Origin of Species" he calculated that about 300 million years (or 70 *mahakalpas*) had elapsed since the end of the Jurassic period. The correct number is about 120 million, but Darwin's contemporaries were thinking in terms of thousands of years for the whole age of the earth, and even those who were most emancipated from ancient tradition gave the total age as ten or twenty million years. Darwin unfortunately withdrew this estimate in later editions of his book.

Biologists use nuclear physics mainly to trace the path of an atom through the maze of metabolic processes ; for example a man is fed with glycine containing a heavy isotope of nitrogen. This appears in the pyrrol groups constituting the prosthetic group, haem, of his haemoglobin. If other amino-acids with "labelled" nitrogen are fed very little appears in the haem. This experiment may be compared with the labelling of a number of ducks in winter in India by rings on their legs. A fair number of these ducks are later found in Siberia, a very few in Germany, and so far none in Britain. Again, Urey finds that the ratio of the two oxygen isotopes in the calcium carbonate of modern molluscan shells is mainly, if not wholly, determined by the temperature at which they were formed. Applying this result to shells from the English chalk, he finds that they were formed at temperatures up to 24°C, as warm as the Indian Ocean today. This method may yet solve one of the at first sight insoluble problems of evolutionary biology, namely the date at which the ancestors of mammals achieved temperature regulation. Biology has not as yet contributed to nuclear physics.

Now consider a phenomenon known for more than a century, namely the polarization of light. Von Frisch has quite recently shown that bees can perceive the plane in which light is polarized, and used the information to find their way when a patch of blue sky is present, since the light from the sky is polarized. Other insects and arachnids have been shown to share this power. How far do other animals perceive physical events which do not affect human senses ? Certainly some fish perceive electrical pulsations, a good many insects perceive radiation in the near ultraviolet. But there is no evidence that any animals perceive magnetic fields, though such perception would aid them in migration. Biologists are also using polarized light for their own purposes. For example, Swann and Mitchison have used it to detect both true crystallization and less complete orientation of protein molecules in living protoplasm, and to measure the thickness of cell membranes. For this purpose a really efficient polarizing microscope is needed. Its design is very different from that of an ordinary microscope. For example, the latter includes compound lenses of different types of glass to correct for chromatic aberration. But the interfaces in such lenses partially polarize light passing through them, and are thus undesirable. In fact the whole theory of microscope design has to be revised, and a number of interesting optical problems arise. Here, then, biology is contributing to practical and theoretical physics.

Chemistry

The relations between biology and chemistry are very intimate. Organic chemistry began as the chemistry of biological products, but it soon achieved independence, developing its own synthetic methods. Biochemistry differs from organic chemistry both in its methods and its aims. It uses biological methods for the detection and estimation of substances which are active in very small concentrations, such as vitamins, hormones and antibiotics ; and it uses special physical and chemical methods for the separation and study of large molecules such as proteins. One of its main aims is the study af chemical reactions occurring within living cells. I have already lectured to the physiological section of the Congress on the use of genetical methods in this study. The reactions are often very different from those devised by organic chemists, and far more efficient. A striking feature of them is the frequency with which phosphoric esters occur as intermediates. I have little doubt that organic chemists will gradually come to copy these reactions, using highly specific catalysts giving a yield of 99% or more, rather than less specific processes giving yields of often under 50%.

But rather than develop this theme I want to suggest to you that certain problems of chemical engineering applicable to plant products may literally be matters of life and death for India. India is not producing enough food for its population. Some people say that it is overpopulated, and that no improvements in agriculture can keep pace with the probable increase of its population. Let us look at the problem from a rather different angle. All or almost all, sources of human food are plants or animals which could be used by primitive man, but whose yield has been increased both by selective breeding and improved agricultural methods. But in industry we are not content with using substances such as wood, iron, and glass which have been known for thousands of years. We also use others, such as aluminium, rubber and plastics, whose very existence was unknown 200 years ago. Is it possible to use sources of food which were not available to primitive men ? I believe so. Men cannot digest grass or the leaves of most trees. They contain too much indigestible fibre, not to mention silica. At present our most efficient way of utilizing grass is to get a cow to eat it, and give us back a fraction of its proteins and carbohydrates in the protein, fat, and carbohydrate of her milk.

However, in the laboratory it is quite possible to separate most of the proteins and the digestible carbohydrates of grass and other leaves from the fibre. While seed proteins generally contain much glutamic acid and are often short of tryptophan and other constituents needed by men, leaf proteins have a much more favourable amino-acid composition. But their separation from fibre is difficult even on a laboratory scale, and at present quite impracticable on a factory scale. A few people are working on this problem in England, but our chemical engineers are more interested in the mass production of explosives than of food. India will get no help from the Soviet Union or the United States. Both countries have plenty of undeveloped land, and ordinary agricultural methods will suffice them for a generation to come, at least. Even if you begin to work on the problem in India tomorrow you would get no substantial increase in food production for 10 or 20 years. But I believe that India ought to look that far ahead.

Agricultural Science

My own science of genetics is, of course, intimately connected with agricultural science. In this field India cannot rely on other countries, as it can to some extent in physics, chemistry, and engineering. The strains of rice which give high yields in Italy and Japan cannot be expected to do so in India. However, Dr. Mukherjee has dealt with problems of plant improvement in his presidential address to this Congress. I shall confine my remarks to the improvement of animal races. Let me take a simple example of the type of work needed. The villagers round Calcutta keep ducks and hens. It is possible to breed hens which can produce a large weight of eggs per year, but to do so you must feed them on grain, so that they compete with men for an important food. On the other hand ducks live wholly or mainly on animals and plants in the tanks, and do not compete with men for food. However, these ducks have not been selected for high egg production, though attempts are being made to acclimatize English ducks at one place in Bengal. My wife has been studying your domestic ducks, and finds that they differ greatly from those of Europe or of China. It may turn out that our European ducks are no more adapted to life in Bengal than are our cattle. If so you will have to form your own breeds, and even in five years a good deal of progress could be made.

Your great problem is, however, of course, the cow. Some people will tell you to kill and eat the old cows and most of the male calves. As a biologist I would say something different. The relation between the Hindu and the cow, at its best, is the best example known to me of symbiosis between two vertebrate species; at its worst, it leads to starvation of men and cows alike. If a people decides to adopt a symbiotic rather than a predatory relation with another species, this raises special biological problems which only they can solve. We in England have got a great deal more milk to drink per man than you in India. This is because each of our cows gets a great deal more to eat than the average Indian cow, and has been selected so as to give a high milk yield if well fed. You will have to breed for higher milk yield, while reducing your cattle population so that each cow gets enough to eat. I see from the programme of your Congress that you are studying methods to render cows of uneconomic type infertile. I am glad that your ethics permit this. For the moment you should certainly breed mainly for high milk production.

But two other aims must be considered. If you are to reduce your cow population without killing cows, you will ultimately have to increase the duration of lactation so that you do not have to breed so often from each cow. Some European breeds stay in milk for over 600 days, and even this number could be increased, perhaps by selective breeding, certainly by hormone injections; though the latter method is not at present economically sound. It may well be that you will also need less bullocks. This will certainly be so if you mechanize your traction. If so you will want to be able to control the sex ratio of your cattle, diminishing the proportion of male to female calves. The sex ratio can be controlled in some insects, and in several amphibian species. For example, by hormonal treatment one can induce an animal which would otherwise be a female to become a functional male, and such an animal has an excess of females in its progeny. If the human race decides to use up its oil supplies in the next fifty years it will be more important to breed a race of cattle combining high milk yield in females and great muscular strength in males. None of these ideals is unattainable, but only Indian biologists will solve them, since in other countries the flesh of cattle is eaten, and bullocks are less used as a source of power. If, however, Indian biologists can solve them they will greatly increase the productivity of their country, and perhaps set an ethical example to the world.

Geology

The relations of biology and geology are, of course, intimate, for palaeontology shares the methods of both sciences, and gives the biologist his most important data for the study of evolution, while allowing the geologist to determine which rocks were laid down synchronously in different areas. There are great opportunities for palaeontology in India, of which I mention only one. Our knowledge of Jurassic mammals is extremely small, largely because most European and North American Jurassic strata are marine. But India possesses terrestrial upper Gondwana beds of Jurassic age, notably the Jabalpur and Raghavapuram beds. These offer a unique hope of finding early mammalian remains.

As an example of the aid which biology can give to geology I take Ma's work on Devonian corals. Living corals form well-marked annual layers if they live far enough from the equator, but do not do so if they live near it, where seasonal temperature changes are slight. Ma considers that the Devonian equator was a good way from the present one, running, for example, through Europe, but that owing to the drifting apart of Europe and North America, it does not form a great circle on the earth's present surface. If this is correct continental drift has occurred. Similarly, from the present distribution of several types of animals, but particularly torrential fish, where the animals of the Western Ghats appear to be derived from those of Burma, Hora has deduced the Satpura hypothesis. According to this hypothesis, there were fairly recently, perhaps in the Pleistocene, hills in what is now lower Bengal, connecting the hills of peninsular India with those of Burma. Whether or not this hypothesis is finally accepted, it has led to researches, both biological and geological, whose results are of value for both sciences.

ANTHROPOLOGY

Physical anthropology, which regards men as animals, is a branch of biology. In the last generation its technique has been revolutionized by the discovery of a set of characters, namely the antigens of the blood corpuscles, which are wholly determined genetically, and not at all influenced by the environment, as for example skin colour and stature certainly are. Unfortunately Indian anthropologists have so far mainly confined themselves to the study of those antigens which are important when blood is transfused. Similar work with all the antigens whose genetics are known would certainly give new data on the racial history of India, as it has on that of Europe. In particular it would throw light on the relation of the primitive so-called aboriginal tribes to the majority of the population, whose ancestors were already civilized when most of Europe was in the tribal stage of culture. It is important that this work should be done as soon as possible in those areas where the primitives are beginning to interbreed with the rest of the population.

Biology can make an important contribution to the knowledge of man by the genetical analysis of domestic plants and animals. As the President of the Indian Republic recently said, human history should not be the story of violent deeds, but of cultural achievements of which we may be proud. The domestication of a plant or animal species is such an achievement. There can be no doubt that poultry, along with a fair number of plants, were first domesticated in India. Bees may have been so. It is much less clear whether, for example, cows and dogs were first domesticated here. It is up to Indian biologists to find out. One method would be to compare the blood antigens of dogs with those of jackals and wolves, a process, by the way, which does not involve the taking of life or the infliction of appreciable pain.

Logic and Moral and Social Sciences

But biology has a still more important relation to the human sciences to whose importance Pandit Nehru referred in his address this morning. If I am asked what is the greatest scientific achievement of the century, I shall point to the great advances in atomic physics associated above all with the names of Rutherford, Planck, and Bohr, but to which Raman, Saha, Bose, and Kothari, to mention no more Indian physicists, have made honourable contributions. Most people, alike in Western Europe, the U.S.S.R., and the U.S.A. would agree with me. So, rather to my surprise, did Mr. Justice Banerji this morning. But for thousands of years Indian sages have said that the most important thing that a man can do is to realise, in thought and action, the unity of all living, or at least of all sentient beings. Sometimes they expressed this unity in terms which I can no more accept than I can accept European mythology, sometimes in more abstract terms such as "Tat twam asi". My own philosophy is decidedly *nastika*, but I am not so dogmatic as to deny the possibility that the Vedanta, or one of the other *astika* philosophies, may be nearer to the truth than my own.

If this is so, then the greatest achievement of 19th century science was Darwin's statement, in highly concrete terms, of the unity of life. And the greatest achievements of 20th century science are the discovery by biochemists of the great similarity, in some cases the identity, of the chemical processes of life in animals, and even in plants, and perhaps above all von Frisch's discoveries in the field of animal language. You will remember that he has shown that one bee can make to others such a statement as this : "there is nectar requiring at least 20 gatherers in apple blossom at 900 meters 12°E of N from our hive". It communicates this information by dancing. The direction of the dance on the comb indicates the direction of the flowers, an upward dance indicating the direction of the sun, an oblique dance 30° to the right of vertical a direction 30° to the right of the sun, and so on. The rhythm with which the abdomen is oscillated indicates the distance, the duration of the dance, the amount of food, while the other bees smell the dancer to determine the nature of the flowers from their scent. Now, so far only the hive bees of Europe and North America have been investigated. Is the language the same for Indian domestic bees, and above all for Indian wild bees, which may represent the ancestors of all domestic races? This problem can only be solved in India. The study of bees is of considerable economic importance. I have seen no domestic bees in Bengal, though there are plenty of flowers. There may be good reasons why bees cannot be kept in some parts of India, but they could certainly be kept over wider areas than at present. Not only would they add to the food supply without taking food from men or cows, they would also improve the fertility of many fruit trees.

Similar work has been done on bird languages in the Soviet Union. These languages are mainly learned, while that of bees seems to be biologically inherited. In Ukraine one species of tit sings two different languages, and the two linguistic groups do not interbreed. Such investigations seem to me as essential a background for social anthropology, for philology, even for logic, as is comparative anatomy for human anatomy. In so far as logic tells us anything about the nature of reality, and not merely about human communication, the laws of logic must apply to dancing as well as to speech. It is, however, clear that dancing, as a method of communication, suggests a "many valued" logic rather than one with a sharp distinction of true and false.

Mr. Justice Banerji told you this morning that whatever progress might be made in positive science, it could not satisfy the soul. May I venture to differ from him ? I believe that the contemplation of living beings can do so. Let me quote three sentences from Francis Darwin's reminiscences of his father, Charles Darwin : "I used to like to hear him admire the beauty of a flower; it was a kind of gratitude to the flower itself, and a personal love of its delicate form and colour". "I think he sometimes fused together his admiration of the structure of a flower and its intrinsic beauty." When observing animals he often stood completely still. "It was on one of these occasions that some young squirrels ran up his back and legs, while their mother barked at them in agony from a tree." Similar incidents of concentration are, of course, recorded of *rishis* in India.

I believe that we can learn moral lessons from animals. Apparently gentle animals such as doves may quarrel, but if so, in nature, one flies away before much harm is done. If however, they are kept in a cage one dove may slowly peck another to death. On the other hand, wolves and ravens fight with their formidable teeth and beaks. But such fights always end abruptly if the vanquished surrenders. Lorenz describes how a wolf which is beaten presents its throat to the victor so that a single bite would kill it. The victor growls, but is unable to bite. Similarly a vanquished raven presents the back of its neck, and the victor never kills it. Unfortunately men are not always so merciful as wolves and ravens. In the past both British and Indian soldiers have murdered prisoners, and today British airmen are dropping bombs on civilians in Korea.

I end on this note for a simple reason. It is entirely possible that within the next two or three years European civilization will largely destroy itself. If you in India continue your present foreign policy you may escape this destruction. If so I hope that you will carry on with the great traditions of our biology, rather than imitate us in self-destruction with weapons provided by the physicists.

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