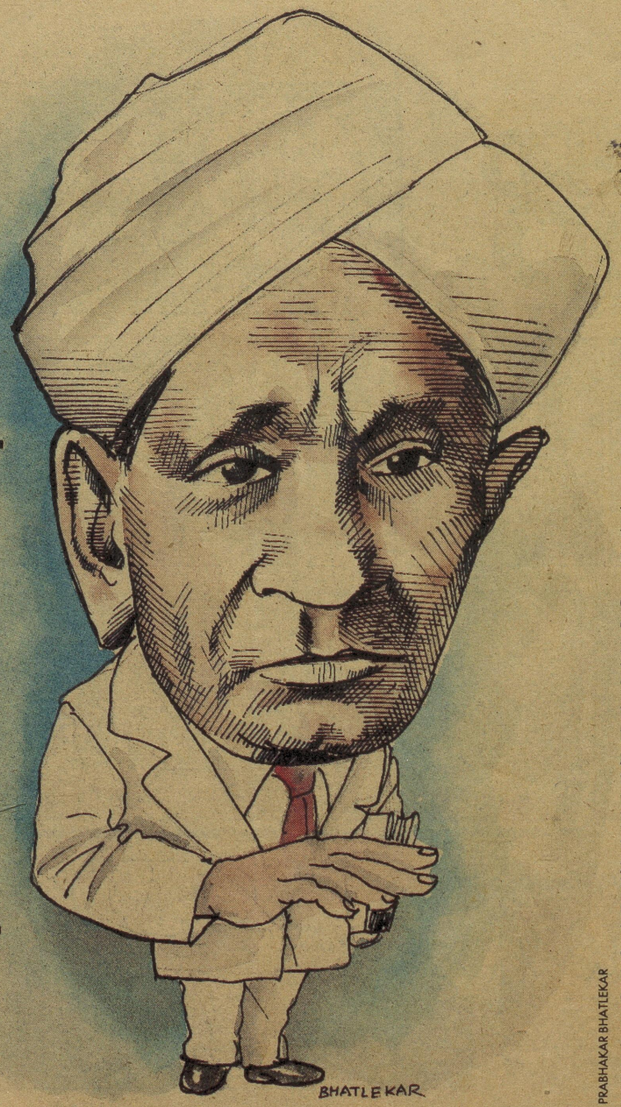
THE RAMAN ANGST

By H.Y.Sharada Prasad

There were the laurels, but there soon followed the criticisms and allegations. The story of C.V.Raman's life is one of strife coming in the wake of success



PRABHAKAR BHATLEKAR

IT has been said of the Romantic poets that they all died young, including Wordsworth, who lived on to be 80. Our best known and most honoured scientist, C.V. Raman, also lived to be 80 and he was productive till the end. His last paper "The Red Oleander and the Purple Petria" was written a few weeks before his death. From his first paper published in a foreign journal when just 18 and still a student, there was not a day when he was idle.

Yet, this insightful biography of the scientist by G. Venkataraman tells us that somewhere halfway through his life, something broke in him and the creative gift deserted him.

The author gives three causes for this: too much praise from an ignorant public, brickbats from colleagues, and indifference, even obstruction, from the bureaucracy.

Raman went through a long stretch of acute depression, during which he resigned from the Royal Society — the only Fellow to have done so after Newton. It is also believed that he was offered the Vice-Presidentship of the Indian republic and he said: "What shall I do with this ship?"

He wanted to be in science and of science. The brilliance was there, as well as the irrepressible curiosity about Nature and its phenomena, but the production was not touched by the flame of creativity. The biographer remarks that Raman was not the only scientist to whom this had happened. He cites the case of Einstein, who was deeply wounded by the persecution of Nazi Germany.

It is not as if the creative element in a scientist or artist comes out only when the going is easy. Often adversity or the world's neglect acts as a spur. There are painters and poets who have holed up in attics forgetting hunger and pain, and given us masterpieces. The sculptor's chisel thrives when the rock resists. But persecution has a different effect. The persecuted man may fight. He may grow into a hero and even become a martyr. But the persecuted scientist will not be able to give that concentrated, all-consuming attention to the little intimation of an idea to enable it to grow into a full-fledged theory.

Raman's experiences were much less brutal than Einstein's. But he was deeply hurt, not once but twice, within five years. He had to quit Calcutta which he loved and which provided opportunity for an accountant to become a Nobel laureate. Not long after there was a deeply searing experience in Bangalore.

The first was mainly a clash of personalities, in which Raman was ranged against P.C. Ray and Shyama Prasad Mukherjee. The second is more instructive for anyone interested in the relationship between authority and the pursuit of the scientific spark.

When Raman went to the Indian Institute of Science in Bangalore, in 1932, as its director, it had only three departments: chemistry, physical chemistry and electrical engineering. It was generally regarded as a place where well-paid people did little work. Raman set about organising a department of physics.

Raman had a basic belief: good science is produced by good scientists. As in Calcutta, fine young minds came to him. Another of Raman's traits was to go about whatever he took up with a European intensity. When money was needed he diverted the funds that the other departments were not using. He also thought of inviting some of the scientists who were leaving Hitler's Germany. One who accepted the invitation was Max Born. Lord Rutherford advised him to take the Bangalore job as the pay was better than what Cambridge could offer! But that only added to Raman's woes.

A certain gentleman called Watson, professor of chemistry, accused Raman of hiring "second-rank foreigners who were unwanted in their own country." So Max Born had to go and the post of professor of theoretical physics was not created. (Another European who would have almost come to Bangalore, but was spared such humiliation, was Schroedinger.)

Raman was also rebuffed in his attempt to get the institute's workshop build some of the equipment his department needed. The governors of the Institute took a serious view of Raman's crime of using money meant for other departments. He was accused of profligacy (as he had exceeded the budget by Rs 9,000) and of misuse of funds.

Raman, the offender, stepped down from the institute's directorship but continued as professor of physics. (He was in his department at 7 a.m. the next day.) A little later, Homi Bhabha joined the department as reader, as he could not go back to the Cavendish Laboratory because of the outbreak of war.

THE biographer has gone to some length to disprove the widely held belief that Raman's trouble was that he was a poor administrator although he was a good scientist. It was essentially a conflict between two approaches to science — 'appropriate science' and the pursuit of the most advanced achievements in science.

Raman believed that "research is civilisation and determines the economic, social and political development of a nation." He also believed that science came from the brain and not from equipment. When one of his pupils in spectroscopy complained that he had only a 1 kW lamp whereas his competitor abroad had a 10 kW lamp, Raman told him: "Don't worry. Put a 10 kW brain to the problem."

The Tatas, who had a major say in the running of the Bangalore institute, chose to side with the British authorities rather than with Raman. Fortunately, the same Tatas, only a few years later, gave full support to Homi Bhabha to set up an Institute of Fundamental Research in Trombay.

This experience drove Raman more and more into himself. Never short on stubbornness and pride, he failed to keep up with the new developments in science. In the words of the biographer, he missed the bus of quantum mechanics. There were moments when he wished he had invested the Nobel Prize money in buying an ounce of radium rather than diamonds, but what absorbed him now was the shape and colour of precious stones and shells and flowers and the magic sounds of music. The biographer, a distinguished physicist himself, tells us that Raman was always weak in his theoretical grounding. It was only for the brief period that a brilliant young mathematician, Pancharatnam, worked with him that Raman produced anything theoretically exciting.

Dr Venkataraman calls Raman's life a tragedy. The second half did not match the first in achievement. He had to live with the knowledge that he had allowed himself to be left behind. He was to hear reproaches that even his Raman Effect had been appropriated from the work of his student, K.S. Krishnan, and was in fact the Krishnan Effect.

Yet he did not bow his turbaned head. When, on his 80th birthday, he was praised by his admirers for the diamond-like lustre of his intellect, he remarked: "I wish someone had said I had the heart of a lion."

Raman was intensely nationalistic but he was never at ease with the post-Independence approach to science. He does not seem to have responded warmly to Jawaharlal Nehru. He spurned an offer of a grant to the Raman Research Institute. He disapproved of the practice of the Science Congress being inaugurated year after year by the Prime Minister. He felt that in the search for development, scientific excellence was taking a back seat.

The biographer, as is only to be expected, writes about some of Raman's contemporaries and leaves us wondering what it would have meant to Indian science had S.N. Bose not lost himself in teaching, had Meghnad Saha not concerned himself with politics and Homi Bhabha not placed institution-building above pursuit of scientific investigation. Raman himself did not receive peer-group support. Maybe his character was his destiny.

♦ *Journey Into Light: Life And Science Of C.V.Raman, By G.Venkataraman, Published by Oxford University Press, India, Rs 325*

The man who saw poetry in science

JOURNEY INTO LIGHT: Life and Science of C.V. Raman, by G. Venkataraman. Indian Academy of Sciences, P.B. No. 8005, Sadashivanagar, Bangalore-560 080. 1988. Pp. 570.

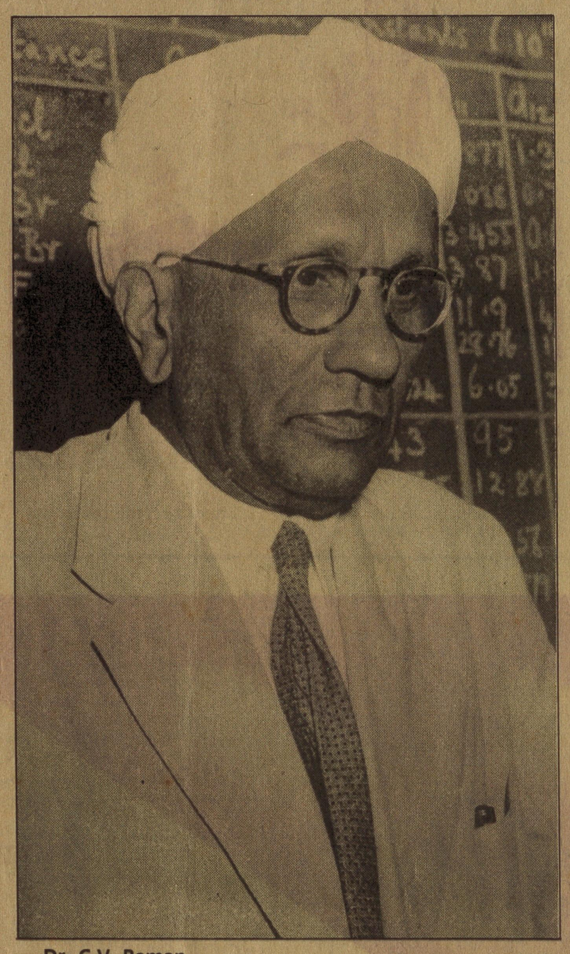
by Rajaram Nityananda

THIS full-length biography of C.V. Raman by G. Venkataraman aptly entitled *Journey into Light* fulfils a long-felt need and will be especially valuable to the younger generation of readers who have had little exposure to Raman's life and work. The book is published by the Indian Academy of Sciences which was founded by C.V. Raman but it is no ritual tribute. The author has critically dealt with both sides of his chosen subject, positive as well as negative.

Given that science was a passion with Raman, it is appropriate that his biographer is a well-known physicist whose own research well qualifies him to appreciate Raman's work. It is still more appropriate that the author belongs to that minority group in the tribe of scientists who can write clearly, informally and indeed grippingly.

Even to one familiar with the basic facts of Raman's life, they make astonishing reading. As a student he races far ahead of his fellows while still years their junior, and is exempted from all physics lectures since they can teach him nothing. Married and a member of the elite financial wing of the civil service by eighteen(!), he carries out research in his spare time, maintaining a rate of publication (today's way of measuring science) which would be the envy of a full-time scientist, in the best known journals of the day. This is made possible by the facilities of the Indian Association for the Cultivation of Science in Calcutta, founded decades earlier by the visionary Mahendra Lal Sircar. In turn, Raman's touch brings this institution to life as a centre of research.

The period before he is thirty, normally regarded as the peak of a scientist's career, passes in this manner, still doing part-time science. Finally, a far sighted Vice-Chancellor, Asutosh Mukherjee offers him the chair of physics at Calcutta University. In a shade more than ten years, he has established a flourishing school and made the discovery which brings the Nobel Prize to India. It is interesting to recollect the advice of Krebs and Medawar (two distinguished British scientists) to those who wish to win a Nobel Prize or otherwise make an impact in science. One must belong to a great school, and must work on important problems. Raman fulfilled both criteria in his own unique way — he founded the school and brought his problem, the scattering of light, to the centre of the stage by his efforts.



Dr. C.V. Raman

When he seems to be at his very peak, hostile forces displace him first from the Association and then from the directorship of the Indian Institute of Science in Bangalore, all within five years. He carries on as the head of the physics department, with mutterings on all sides that his physics is old-fashioned and his administration flawed. But he continues to inspire a new generation of students and many pioneering studies are carried out. The full significance of some of them is in fact appreciated only decades later.

At the same time, he confronts one of the world's best-known theoretical physicists, Max Born, on his home ground — the motion of atoms in crystals. To the end he can never acknowledge that he is in error. Retirement to an institute of his own follows. For one more decade, yet another generation of students draws inspiration from him. And finally his last ten years with just two or three people to assist him, are spent in comparative isolation investigating vision. The eyes that saw so much are now turned inwards to see themselves and he remains an active, if controversial, scientist to the last.

EXCITING as it is, Raman's story forms only a part of this book. There is a very interesting discussion of the historical background of how different sections of Indians reacted to western influences and science in particular. And there is a vivid description of other personalities linked in one way or another with Raman. One is Meghnad Saha, who established himself as a scientist against tremendous odds and wrote one of the fundamental papers of modern astrophysics. The deep rift originating when he felt slighted by Raman (not without justification) influenced many later events at the Association, the Institute and in the scientific community as a whole.

Another well-known figure whose direct bearing on the events of Raman's life is perhaps less is Homi Bhabha. Both Saha and Bhabha were involved in the post-independence development of Indian science and both were theoretical physicists. Venkataraman gives an interesting contrast between them and Raman. Reading this, it seems he has left unsaid and perhaps implicit the most striking difference. Saha and Bhabha each had somewhat more than a decade of intense research activity (as distinct from administration). One can trace a few major scientific themes and each left behind some really outstanding students. (Not much more is given to most great scientists!)

With Raman, all these figures can comfortably be multiplied by three if not more. The sheer volume of activity and the energy it implies is staggering! Quite a few of Raman's students stand out by their later achievements. Since many are still alive and kicking, this is a tricky subject but one may mention K.S. Krishnan, S. Bhagavantam, G.N. Ramachandran and S. Pancharatnam. Inevitably, the administration of large organisations drew some away from sciene but thankfully not all.

Venkataraman gives a spirited defence of Raman against some remarks by Fabelinskii, a well-known Russian authority on light scattering. The point is that Landsberg and Mandelstam in the Soviet Union also independently discovered the effect now named after Raman at about the same time. It is perhaps natural that their countryman should feel that they were denied a Nobel Prize, and seek to pick holes in Raman's work. The contrast in style between the Moscow and Calcutta groups is well described. The first is slow, steady and orthodox while the second relise on intuition, visual observations, rapid changes in direction, conjectures and leaps - some in the wrong direction - but above all a single minded pursuit of the goal.

The section in which he tries to counter Fabelinski's remarks is a place where one might differ from Venkataraman's perspective. It is abundantly clear that the prize meant a great deal to Raman (was he the first and last winner to use N.L. after his name?). History can perhaps afford to take a more balanced view and the precise dates of individual papers and whether they referred to each other seem less relevant today.

One of the most interesting relationships is that between Raman and Born. Their scientific differences have already been mentioned. One even hears statements to the effect that but for Raman, Born might have settled in India. This part of the book sets the record straight with enough extracts from the original letters and other documents to leave no doubt. In spite of totally different styles and strong differences on specific scientific issues, Raman went out of his way to create a chair of mathematical physics for Born at Bangalore. This move was criticized and ultimately sabotage by a clique consisting of a few submediocre Englishmen at the Institute and their Indian collaborators.

For his part, Born, while fully aware of many of Raman's failings, scientific and personal, describes him in his letters as easily the most outstanding scientist in the country and



Dr. Raman with colleagues

completely clears him of all the charges raised. This was in the year 1937 when Raman was ultimately forced to resign as Director. In later years, this healthy mutual respect did indeed degenerate to bitter personal attacks on both sides.

EVENTS and personalities aside, a major theme of the book is Raman's science. Keeping in mind the requirements of different readers, Venkataraman handles the topic at three levels. There are many quotations from the original papers with comments and clarifications skillfully woven in. These sections should certainly give all readers a feel for Raman's scientific (and literary!) style.

Then there are more technical sections and chapters, the more demanding ones marked out by a star, which are meant for students and practitioners of physics and related disciplines. These are aimed at the many people fully equipped to understand Raman's contributions who are nevertheless quite unaware of them. There is still a difficult choice of material and presentation to be made here since the aim is neither to write a textbook nor to give a superficial overview. This reviewer was left with the feeling that separate technical appendices might have interfered less with the flow of the book.

One of the memorable chapters describes Raman as a populariser of science — not just its content but also its spirit. Perhaps these writings come closest to revealing his direct communion with natural phenomena and his ability to view them both scientifically and poetically. It is to be hoped that these lectures, first given over All India Raio, will be made widely available to students in our country.

The extensive notes bring out many fascinating sidelights and there are many references for those who would like to go back to the sources. The figures are very well planned and executed and there are a large number of photographs both scientific and documentary. For both its sweep and detail, it is unlikely that this biography will be surpassed. If there is one area where a reader might ask for more, it concerns Raman the man. The author does indeed give us some fascinating glimpses. A newly arrived research student is taken on a whirlwind tour of the lab and finds his Nobel Prize winning guide helping him to move furniture and settle down.

An earlier generation of students in Calcutta see him exercising on the lawns in front of the Victoria Memorial. On the other hand, he is seen to be extreme and unyielding in his attitude to people and institutions in which he had lost faith. In his later years, he flayed Government institutions, even when one was headed by Krishnan, his former student!

Overall, the personal glimpses are all too few and by and large we see the public figure, a legend in his own time. What was the private Raman like? This question involves sifting correspondence and hearsay accounts. One can readily understand why Venkataraman has usually stepped clear of this slippery ground, and one wonders if any later biographer will venture there. For now, the life and science of C.V. Raman have found their chronicler.

Significant tool

MAOISTS IN ANDHRA PRADESH: by Shantha Sinha. Gian Publishing House, 4348, Madan Mohan Street, 4-C, Ansari Road, Daryaganj, New Delhi-110 002. 1989. Rs. 280/- Pp. 325.

by N. Jayaram

SCHOLARLY literature on Maoism in India, popularly known as the Naxalite movement, has mostly focussed on its rise, growth and decline in West Bengal. Paradoxically, it is in Andhra Pradesh that this movement seems to have struck deeper roots, acquired the support of sections of both the intelligensia and the indigent, and has become a force to reckon with. This makes Shanta Sinha's, what is perhaps the first detailed study of Maoists in Andhra Pradesh, doubly significant.

This "brilliant work," writes Bipin Chandra in his succinct and dissective Foreword, is based on "detailed documentation, a firm grasp of the ideological, strategic and tactical issues involved, and a sympathetic, though not uncritical approach." This is no exaggeration indeed.

What is particularly praiseworthy about Sinha's presentation of rich narrative data is the pleasantly absent hairsplitting, historical speculation and sophisticated theorisation. If only the text had been proof read, it would have made the book more absorbing.

Sinha concedes that it is dangerous to rely excessively on the party writings as source material, as they are given to gross exaggerations and naive rationalisation. But then the police reports too are tarred with the same brush. Hence, she adopts "a balanced approach" by restricting herself to "only those incidents for which corroboration is forthcoming."

Andhra Pradesh constitutes a veritable laboratory for the study of the Maoist movement, in that it contains a large variety of groups subscribing to almost all shades of Maoism. This, coupled with the immense regional variations, provides a unique arena for comparative analysis of the progress, problems and prospects of extremist radical revolutionary movements.

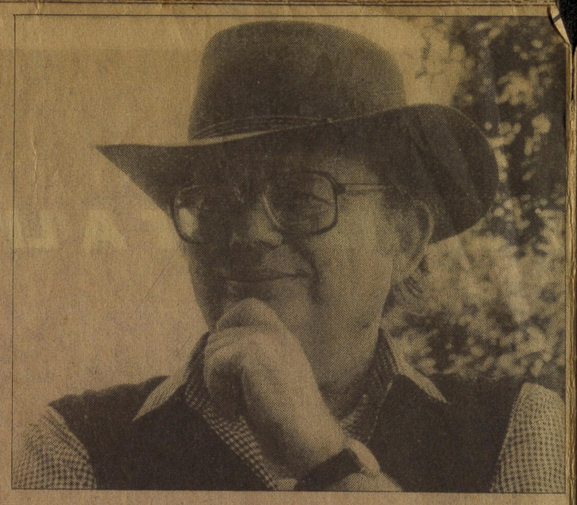
BROADLY, three stages of analysis are delineated by Sinha. The first covering the nascent years of the movement in Srikakulam (1957-67), the second relating to its maturity and spread in the benighted tribal areas of Telangana (1968-75), and the third dealing with the post-emergency period. Though Sinha has discussed at length the Srikakulam phase, it is her firm conviction that "the true nature of the Maoist movement in Andhra Pradesh is reflected by the happenings not so much in Srikakulam as in Telangana."

Sinha's analysis shows that the Maoist movement, far from being static in character, has been in a continuous state of evolution. Of course, "the movement has neither been mammoth in proportion, nor startling in effect." Some of its weaknesses, theoretical as well as tactical, are also highlighted by Bipin Chandra in the Foreword.

Among them are, on the one hand, the lack of a critical appraisal of the development of capitalism in India, the changes in agrarian structure being introduced from above, the role of democracy and welfare statism in strengthening the State; and on the other hand the equation of violence with the working class, the peasantry and revolution, and of non-violence with the bourgeoise, landlords and the maintenance of the status quo.

Nevertheless, it can hardly be gainsaid that the movement has attracted a high turnover of sympathisers, which according to Sinha "has been one of the factors which has given it strength." If the movement has derived dynamism from this, its gradual adaptation to local conditions has kept the flame of its hope still alive.

To conclude, in Bipin Chandra's words, "the rich experience of the Maoist movement should enable the forces of socialism to draw important theoretical and strategic conclusions:" otherwise... the adage that those who refuse to analyse the past are condemned to reliving it, would continue to apply to them. All those who want to make a basic analysis of the past of the communist movement in India, or who want to learn from the past, will find in Dr. Sinha's work an indispensable tool."



A Bond with the hills

by Rakesh Kumar

LIVING simply on the outskirts of the hill station of Mussoorie, and quietly turning out his short stories, essays and children's books, is India's own Bond... Ruskin, now celebrating 30 years of freelance writing.

Ruskin Bond is not a *nom-de-plume*. His father, Aubrey Bond, named him Ruskin, after the Victorian essayist, John Ruskin, and must have wanted his son to be a writer.

"My father taught me to read and write before I went to school," says Ruskin. "He died when I was only ten, but he had given me his love of books, music and art, and in this way he was to remain with me all my life."

Ruskin was born in Kasauli (Himachal) just over 55 years ago. His first book was published when he was eighteen, and today his literary journey is still in progress. Last year, Penguin-India published a collection of his stories, *The Night Train at Deoli*. Its success has prompted them to bring out another collection, *Time Stops at Shamli*, which will be released in October.

Critics haven't always been kind. Some think he's old-fashioned... to romantic. But Sue Earle, writing in Hong Kong's *Morning Post*, had this to say: "He has done his adopted country a service by showing a side of it that many readers outside India may not suspect exists. He writes about the ordinary people and their everyday lives with great understanding.... HE took to writing for children about 20 years ago, and now much of his work is in this genre. A recent book, *Ghost Trouble* (Julia MacRae, London) was an April selection of Letterbox Library, a British book club promoting non-sexist, non-racist literature. Another short book, *Getting Granny's Glasses*, was nominated for the Carnegie Medal.

Freelancing anywhere is a precarious occupation. In India, it is almost impossible. There were many years of struggle, of not knowing where the next cheque would come from, of sometimes finding himself saddled with dubious publishers.

"There are two great lies in the world," says Ruskin cheerfully, "One is, 'I love you more than I've ever loved anyone!,' and the other is, 'The cheque is in the mail.'"

Still, he has come through it all, with his independence and good humour intact, free to write about the things he likes most — children, old people, trees, flowers, animals... He has had several opportunities to live and work abroad, but he has never wavered from his decision, made many years ago, that he would remain in India, and preferably in the hills.

"When I first came to these mountains, a young man of thirty," recalls Ruskin, "I had no idea that I would still be living in them, twenty-five years later. But they did not take long to cast their spell over me. Once you have lived with mountains, once they are in your blood, there is no escape. You remain their prisoner, a willing slave. And if you find you must go away, you will come back, again and again."

The origin of speeches

NO, PRIME MINISTERJI

by John Daniel

AFTER having spent his spare time for months with Sherlock Holmes, absorbing as much as possible of the great fictional detective's deductive reasoning, the Secretary made practical use of his acquired powers in the Prime Minister's office. For several days he keenly observed the state of the Prime Minister's hair.

Was it combed or uncombed? Smoothed down or windblown? A wisp straggling over his ear? Or drooping over his forehead? And then one morning when the Prime Minister arrived with his hair in disarray — straggling over his forehead, his right ear, left eye and one wisp sticking up like some kind of antenna — he announced his conclusions.

"Prime Ministerji, the clues indicate that your election campaign has really hotted up."

"Right. But what clues are you talking about?"

"Sir, the clues on top. It's clear that you don't even get time now to comb your hair."

"Actually... I lost the comb I used to carry around."

"Maybe. But obviously you can't find the time to buy another. And from the constantly ruffled state of your hair I conclude that you are constantly travelling these days. Far and wide.

Through windy places. By jeep, helicopter and plane. That could mean one thing only. The campaign has turned red hot. Why else would you travel so much within the country?"

The Prime Minister watched his Secretary. "That's logical. Of course, you could have known that easily without having to analyse my hair style."

"How, sir?"

"By reading the newspapers."

"Frankly, sir, in the office I have no time to sit and read the papers. And at home... I stopped buying a paper after they increased prices. I can't afford it now."

The Prime Minister's face lit up instantly. "Really! Are you telling me you don't read **any** newspapers?"

"No, sir . I mean, yes, sir."

THE PM jumped up. "Hip-hip-hooray! That means it's working! Secretaryji, it's working!"

"What's working, sir?"

"Our strategy. This is the first concrete proof. And coming from you it's hundred per cent reliable. After all it's... well ... straight from the horses' mouth."

"Horse? Me, sir?" asked the mandarin querulously.

"No, no. Sorry. I didn't mean to insult horses. See... if, like you, people all over the country stop reading newspapers... they will **have** to depend on Doordarshan and AIR for their news."

"That's deductive reasoning worthy of Sherlock Holmes himself, sir," said the unmollified mandarin in a sarcastic tone.

"Thank you, Secretaryji. And that means we have a captive audience. They'll get a full dose of my election campaign."

"Sir, let me remind you that the Opposition are holding countryside protests against misuse of the official media."

"But if anything... this is useful misuse."

"They are protesting outside every Doordarshan Kendra and AIR..."

"Why should we bother? We won't give them a minute of coverage. So the public will remain ignorant about their protests. Further... as a matter of fact... there is **no** misuse at all."

"You mean there is no truth in the Opposition's claims?"

"No. A study by my Ministry of Information and Broadcasting... if I remember the figures correctly... shows that in February this year I took only 4% of Doordarshan's time, in March only 2% and April only 6% ."

"But, sir, whenever I watch Doordarshan half the news is usually **of** you, **by** you and **for** you."

The PM laughed aloud. "That sounds like half a good redefinition of democracy to me. But the point, Secretaryji... is that you haven't got the point yet. My Ministry's study was conducted on the basis of the total 24-hour viewing time. Not news time alone, you see? For example, do I ever appear in the middle of a toothpaste ad and claim that my teeth are the strongest and whitest?

No! Never! Have I even once popped up in the middle of Ramayan and made a speech on the endless benefits of Panchayat Raj? No!"

The mandarin nodded dumbly.

"To get a captive audience," the happy PM went on, "was the essential first ten for the success of our strategy. Now... with the help of my pioneers... I can go ahead and captivate them all."

"Pioneers, sir?"

"Yes, pioneers. Those remarkable men whom I have let loose on the country. Oh... you remember the Star Trek series?"

"Yes, sir."

"In Star Trek the crew of the Enterprise are exploring the outer reaches of space where no man has ever been before. Likewise, my pioneers go around making speeches, all the time exploring the outer limits of propriety and decorum... where I, or anyone known to be sober, has never been before. Oh, they sometimes even cross the limits.

They're doing this in order to test the public reaction for me... in advance. I am therefore greatly indebted to these pioneering men. In fact, I have no hesitation in giving them considerable credit for the origin of speeches."

"Species? Sir, I thought it was Darwin who..."

"No, no, Secretaryji," said the PM impatiently. "Speeches. The origin of **my** speeches. See, these pioneers can get away... saying anything which comes to their heads. Why? Because the public look on them as clowns."

"Oh, I see. I suppose you include among them all your supporters who talks if they were K.K.?"

"Peekay," corrected the PM.

CONFUSED, the mandarin said, "I don't think you have any Minister whose initials are P.K."

"Not initials, Secretaryji. Out of their affection, their total devotion to me... I mean, the country... these clowns always talk as if they have had one too many.

Like... like in that old film song, Secretaryji. The one which goes... yes... *Mohabbat me aise kadam dagmagaye, Zamana yeh samjah ki hum peekay aye, Peekay aye.*

You follow? When they slash the Opposition, make the most outrageous or cutting accusations against the Opposition leaders, the public just think that... that..."

"Woh peekay aye?"

Exactly. The public don't bother... but I can watch their reaction and see what the clowns get away with. And then... I know exactly what to say in my own speeches. And how to sock the opposition hard... particularly when I take the fight to them by visiting the states they rule."

"What an excellent strategy, sir. Though... with newspapers out of reach of most people and DD and AIR captive... it looks as if it's going to be a one-sided fight. Sir, you'll be like a boxer who is engaged in a championship fight against a punching bag."

The PM smiled broadly. "Secretaryji, that's the kind of fight I love. Where I can hit them anywhere... with my eyes closed... and they can't touch me."

"But that may be unethical," warned the mandarin. "Even risky."

"Why? Because, sir, with your eyes closed you might... by mistake... sock them under the belt."

The PM thumped the table and laughed. "That's impossible!"

"No, no, Prime Ministerji! It's possible. Just try socking someone... not me... with your eyes closed."

"Secretaryji, the possibility just doesn't arise. You're forgetting the **most** important fact."

"Oh. What's that, sir?"

"As far as we know... not a single Opposition leader wears a belt."

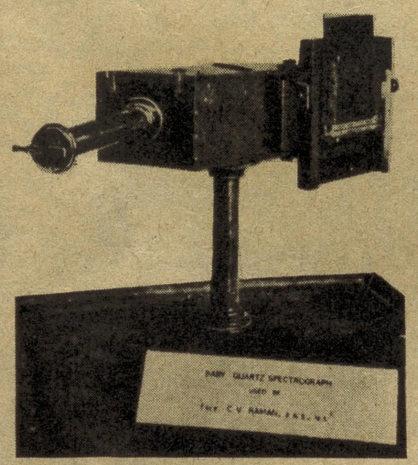
Sixty years of Raman effect

A scientist looks at how it changed study of molecular structure

IN the year of Raman's birth centenary, the Raman effect of light is 60 years old. The centenary was celebrated on November 2 in Calcutta where Sir C.V. Raman did his work which got him the Nobel Prize. As is well known, he had given up a lucrative government job as accountant-general to accept a Palit professorship in physics so that he could devote all his time to research.



Krishnan and Raman (seated)



Raman's spectrograph

A major part of his study was on the scattering of light as it passes through different substances. The Raman effect is a phenomenon observed in the scattering of light as it passes through a material medium; the light suffers a change in frequency and a random alteration in phase or change in step. The Raman scattering is thus distinctly different in both these respects from Rayleigh and Tyndall scattering named after the illustrious physicists who discovered them in the 19th century. In Rayleigh and Tyndall scattering, the scattered light, as it passes through the medium, has the same frequency as the unscattered light had before entering it and bears a definite phase relation to it.

The intensity of Raman scattering is roughly one-thousandth of that of Rayleigh scattering in liquids and smaller still in gases. Owing to its low intensity, the Raman effect was not discovered until 1928, although the scattering of light by transparent solids, liquids and gases had been known many years before.

A few years before the discovery of the Raman effect, A.H. Compton had observed frequency changes in X-rays scattered by electrons. Known as Compton effect, this won its discoverer a Nobel Prize in 1927.

Partly prompted by this, Raman and K.S. Krishnan examined sunlight scattered by a number of liquids. Using complementary filters, they found that there were frequencies in the scattered light that were lower than the frequencies in the filtered sunlight. Then, using the light of a single frequency (monochromatic) from a mercury arc they showed that the new frequencies observed in the scattered radiation were characteristic of the scattering medium. Within a few months of the announcement of this discovery, Soviet physicists Landsberg and Mandelstam announced their independent discovery of the existence of the effect in crystals.

The collection of new frequencies in the spectrum of monochromatic radiation scattered by a substance is characteristic of the substance and is called its Raman spectrum. This is of great interest in the spectroscopy of molecules and crystals. Thus Raman spectroscopy is of great value in determining molecular structure and in chemical analysis, since the manner in which the frequency of the incident light is altered is a tell-tale signature of the nature of the substance through which it has passed. Molecular, rotational and vibrational frequencies can be determined direct and from these frequencies it is possible to find the molecular geometry or at least molecular symmetry.

Much can be learnt about the arrangement of atoms in a molecule from information about the characteristic Raman frequencies of groups of atoms. Raman spectra and infrared spectra often provide complementary data about molecular structure.

Study of complex structures of biologically important molecules is another application. Normal and resonance Raman spectroscopy are valuable techniques in molecular biology. Raman spectra also provide information in solid state physics especially in the electronic structure of solids. Applications in analysing trace elements and in pollution control are also now common. The advent of modern lasers has led to resurgence of interest in the Raman effect and to the discovery of a number of related phenomena. The laser beam can be easily used to excite the Raman effect. Argon and Krypton-ion lasers are usually used as they have high continuous wave power but tunable dye lasers are used for exciting resonance Raman scattering.

The mechanism of Raman effect can be considered either by the corpuscular (particle) picture of light or from the viewpoint of wave theory. Both pictures merge in the basic quantum theory of radiation. Corpuscular model of light scattering envisages light quanta or photons as particles having linear and angular momenta. Passing through a material medium, these photons collide with atoms or molecules. If the collision is elastic, the photons bounce off the molecules with unchanged energy and momentum and hence unchanged frequency. Such a process gives rise to Rayleigh scattering as the light frequency remains unchanged. If the collision is inelastic, the light photons may gain energy from, or lose it to, the molecules.

A change in the photon energy must produce a change in the light frequency. Such inelastic collisions are rare compared to the elastic ones and the Raman scattering is correspondingly much weaker than Rayleigh scattering. If the light frequency is reduced owing to the photon losing its energy to the molecule, we get the so-called Stokes lines. If the light frequency is increased by the photon gaining energy, we have the anti-Stokes lines.

The temperature of the scattering molecules is an additional factor which affects the intensity of frequencies higher than the exciting frequency (i.e., the anti-Stokes lines). The anti-Stokes lines, having higher frequencies, correspond to photons having higher energy than the exciting light and this energy must come from the molecules. Anti-Stokes lines vanish at absolute zero temperature. At non-zero temperatures, intensity of an anti-Stokes line to a Stokes-line is given approximately by the ratio of the number of molecules which can give up the corresponding energy to the number which can accept it from the incident light wave.

Development of lasers led to the discovery of a number of kinds of Raman scattering, such as the resonance Raman effect. When the exciting photon falls within the frequency range of a molecular absorption band in the visible or ultraviolet spectrum, the radiation may be scattered by resonance fluoresence or resonance Raman effect. Both these processes give much more intense scattering than the non-resonant Raman effect. Thus the main characteristic of the resonance, compared with the normal Raman effect, is its intensity which may be larger by two or three orders of magnitude.

The mechanism of the stimulated Raman effect depends on the coherent pumping of molecules of the sample into an excited vibrational state by the powerful electric field of a laser beam. The coherent radiation so produced is called stimulated Raman scattering.

The development of tunable lasers has led to a special technique for stimulated Raman scattering called coherent anti-Stokes Raman spectroscopy (CARS). In this technique, two lasers are used, one of fixed and the other of tunable frequency. The two beams enter the sample of angles differing by about two degrees and simultaneously impinge on the sample molecules. Whenever the frequency difference between the two lasers coincides with the frequency of a Raman-active vibration of the molecules, emission of coherent radiation (both Stokes and anti-Stokes) is stimulated. Thus the total Raman spectrum can be scanned in stimulated emission by varying the frequency of the tunable laser. The advantage of CARS, in addition to high intensity of scattering, is that its elevated frequency avoids interference from sample fluoresence whose frequencies are always below that of the exciting radiation.

Today Raman effect has gained paramount importance in a number of routine studies to analyse the composition of different kinds of materials.

—C. SIVARAM

The author is a scientist at the Indian Institute of Astrophysics, Bangalore

He disliked politicians



LIKE most other scientists, Raman was intolerant of mediocrity and overexercised authority. While working in Rangoon, Raman's superior, the accountant-general, was an Englishman who did not have a high opinion of the dark-skinned natives'. Once Raman wrote a note on a file, contradicting the Englishman's note. Raman was promptly summoned to his superior's overbearing presence and told: "If I tell you that this black ink is red, you have to say, 'yes, sir'." Raman retorted: "Sir, if you said that, my duty would be to say, 'you are either blind or mad or both'."

The snub to the Englishman did not ruin Raman's career; he already had a reputation as a more efficient and meticulous officer than his superior.

Raman thought that science was too serious a pursuit to let politicians interfere in it. He did not like politicians being invited to scientists' gatherings. He refused to attend an annual meeting of the Indian Science Congress because a celebrity politician had been invited to open the proceedings. His bitter comment was: "Where else in the world do you find politicians opening a science congress? I don't understand how a self-respecting scientist can sit and listen to the outpourings of ignorant politicians."

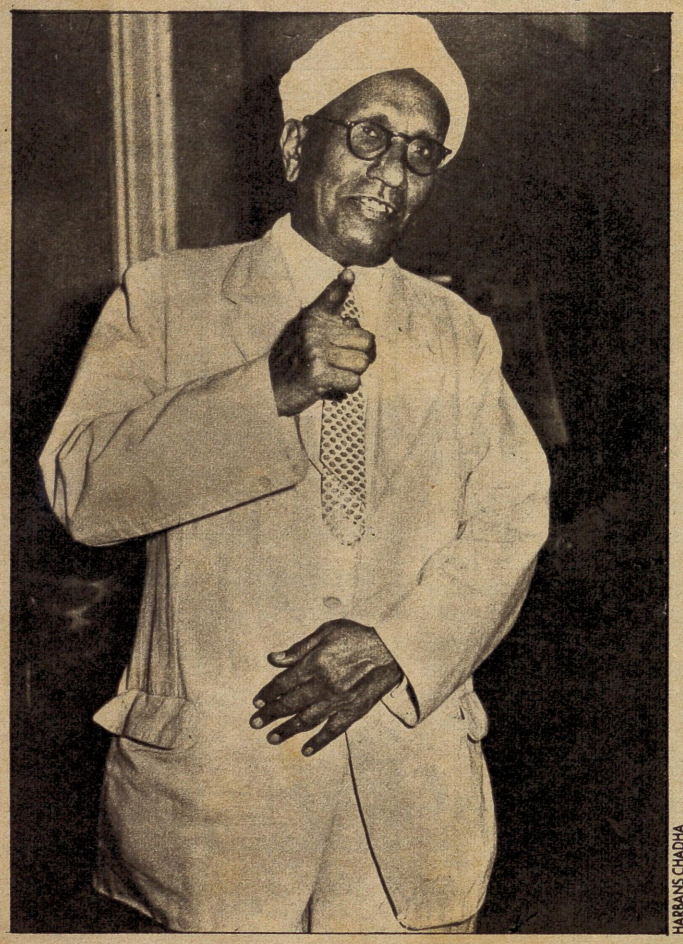
Of course Raman could still have his way for he was different. He did not have to curry favour with anyone for his career.

THE OTHER SIDE OF GENIUS

In the early years of this century, when the scientific establishment in the country was just emerging from the shadow of British domination, a major figure on the national firmament was the brilliant C V Raman. The Nobel laureate and head of the Indian Association for the Cultivation of Science in Calcutta, is now the subject of a raging controversy.

Charges and counter-charges have been traded over the allegation that Raman was forced to leave Calcutta because of opposition from a clique of Bengali scientists led by the scientific stalwart Meghnad Saha.

Santimay Chatterjee and Enakshi Chatterjee profile the controversy.



HARBANS CHADHA

In the early 20th century British India, government jobs used to be the most coveted. It was during this time that a youth who was working in Calcutta, while riding down 210, Bowbazar Street, chanced upon a particular building from the tram-car. The signboard over the main entrance instantly drew his attention. He got down there on his way back from office and made enquiries.

For him that place—the Indian Association for the Cultivation of Science (IACS)—was like an Alladin's cave. It comprised a small auditorium, a few rooms, some scientific equipment for practical classes and some instruments. However, there was something else in it—the atmosphere was pervaded by a rather impossible dream of its founder, Mahendralal Sircar. The dream for an institution where Indians would pursue experimental research in science as per their wish, independent of British intervention of any kind. It must have struck a sympathetic chord in that young civil servant's heart, who was none other than the scientist Chandrasekhar Venkata Raman.

C V Raman is the best example of what can be achieved by undaunted willpower and sheer dedication. It is common knowledge that without stirring out of the country he brought world fame to India's scientific pursuits at a time when she was reeling under foreign domination. However, the focus of our discussion is somewhat different. Raman was associated with the IACS in Calcutta between 1907-1933. He took charge of the Indian Institute of Science, Bangalore on April 1, 1933. In 1914 he was offered the prestigious Palit professorship by Sir Asutosh Mookerjee, the then vice-chancellor, Calcutta University, which he accepted in 1917. While he was away in Bangalore, he retained the post of Palit professorship to keep his options open. Finally, he decided in favour of giving up the Palit professorship on June 20, 1934.

A controversy is going on, which has diffused many issues by distorting facts and disseminating falsehood.

In a book entitled *Journey into Light* written by Dr G Venkataraman and released by prime minister Rajiv Gandhi last year, certain baseless falsities were given credibility. In Pune at the Science Congress meeting the same year its author repeated his claim that a Bengali clique was particularly active in ousting Raman from Calcutta. However, the reasons given in support of his theory are groundless and based on hearsay, as he himself has admitted. The circumstances that prompted Raman's departure from Calcutta are easily traceable, even though a series of false rumours have shrouded the actual course of events. The assumption that Raman was made to leave Calcutta is being persistently believed in some quarters.

But what were the factors that triggered off the rumour? What is the real truth, after all?

After its founding father's death, Dr Amritalal Sirkar became the honorary secretary of the IACS from 1904 to the time of his death in 1919. Professor C V Raman then took over and remained in office till 1933. During his tenure, Raja Pyarymohan Mukherjee became the council president, followed by B C Mahatab and Sir Rajendranath Mukherjee. Shortly after, Dr K S Krishnan, then a reader at Dacca, was made the honorary secretary. Raman himself assumed the post of the president. During Amritlal's tenure Raman used to enjoy the full freedom of utilising the facilities. As secretary of the IACS, he was virtually the supreme authority of the institution. Councils were formed with members approved by Raman. Even if anyone ever took objection to it, it was never made explicit.

Not satisfied with this, Raman thought of effecting some fundamental changes in the constitution of the IACS. The constitution provided for two categories of membership—ordinary membership and life membership. One became an ordinary member by paying a nominal membership fee. After their membership was proposed and seconded, it had to be endorsed by the managing committee. But if someone paid Rs 500 or more, or donated a sum of Rs 250 in the Mahendralal Sircar Memorial Professorship Fund, he could become a life member. It did not require any approval by the managing committee. But Raman wanted to change this. His idea was that life membership should also be made subject to the approval of the managing committee. To make it effective he needed a special general meeting to be followed by the annual general meeting.

Things happened rather fast. The decision to change the constitution was taken at the managing committee meeting of June 10. A special general meeting to be followed by the annual general meeting was convened on June 19. Somehow the information leaked out and many people including Dr Shyamaprasad Mookerjee, the son of Sir Asutosh Mookerjee, (who became the vice-chancellor, Calcutta University, the same year) came to know of it. There were certain impediments as regards payment of donations to become a life member. To seek a way out, Justice Ramaprasad Mookerjee was consulted. He opined that even the IACS trustees could accept donations. Shyamaprasad almost overnight succeeded in enrolling 68 life members, each paying Rs 250. For this he sought Meghnad Saha's help.

Saha was then head of the department of physics, Allahabad University.

As in any other summer vacation Saha with his family had come to visit his brother at Baranasi Ghosh Street, Calcutta. Saha himself was a life member of the IACS since 1926. But he never took any interest in matters of the IACS.

On June 19, Raman tried in vain to stop Krishnan, the IACS secretary, from entering the hall (for without the secretary the meeting could not proceed). At last, Shyamaprasad took control of the situation and Raman with a few of his supporters was persuaded to attend the meeting. A detailed description of the meeting was published in the *Ananda Bazar Patrika* (Bengali) as well as in *Amrita Bazar Patrika, Advance* and *Forward* (English). Headlined 'Efforts of Sir Raman Thwarted' the extract from *Ananda Bazar* (June 20, 1934) is given below:

'Sir C V Raman took the chair and gave a long speech during which he tried to justify his past actions and future plans related to the science association. A bitter debate ensued. But the meeting proceeded in an orderly fashion. Before ending his lecture Sir Raman expressed his desire to leave the post of the presidentship of the association. Then Sreejukta Shyamaprasad Mookerjee moved an amendment that the proposed changes in the constitution be placed again before the managing committee for reconsideration. Sri Mookerjee said that if these modified rules are accepted, then that would stop anyone from becoming a life member without the approval of Sir C V Raman and a handful of his own chosen men.



COURTESY/SANTIMAY CHATTERJEE

Meghnad Saha gave a detailed account of Raman's work in an article and also hinted at the controversy amongst the European scientists regarding Raman's Nobel Prize. The terms of tribute revealed the deep regard and respect Saha had for Raman. Still, it does not rule out the possibility of discord between the two. But it was a clash of opinion between two groups on essentially administrative issues and not on a personal level.

'Shyamaprasad Mookerjee's amendment was unanimously accepted.'

This briefly is the account of the snapping of ties between Sir C V Raman and the IACS. Dr K S Krishnan however retained the Mahendralal Sircar professorship and worked with full liberties to build up his own laboratory. His Dhaka colleagues joined him here. He worked on crystal magnetism which was to bring him the fellowship of the Royal Society in 1941. In all fairness it should also be mentioned here that the Raman effect is now being described by the *Encyclopedia Britannica* as being jointly discovered by Raman and Krishnan.

The events leading to Raman's break with the IACS managing committee were such a shattering blow to his ego that it blurred his sense of judgement altogether. After this incident he not only made very few visits to Calcutta but what is more unfortunate, nurtured an unreasonable hatred for the Bengalis.

His high opinion of the Calcutta school of physics underwent a drastic change after 1934. Once he settled down in Bangalore he started airing the view (in writings, speeches and private conversation) that Calcutta's importance as the nucleaus of creativity had declined and her place was gradually being usurped by Bangalore. His unseemly haste in forming the Indian Academy of Science is an outward manifestation of this change of opinion. This hurried attempt very naturally triggered off a violent reaction.

It seems that almost overnight Raman's attitude underwent a sea-change. He became intensely averse to Calcutta's scientific heritage and pursuits to which he was so much indebted. From the city this antipathy extended to its inhabitants. In an article published in the August 1942 issue of the *Sunday Chronicle* the writer Madan Gopal has this to say: 'His (Raman's) prejudice against Bengal, for instance, is very deep-set. He sees nothing good in Bengal and sincerely believes the Bengalis have made no contribution whatsoever to the life of the country.'

There is no dearth of such instances. The renowned German theoretical physicist (who was yet to get the Nobel Prize) Max Born, whom Raman had offered a permanent professorship in the Indian Institute of Science, Bangalore provides an interesting anecdote in his book, *My Life: Recollections of a Nobel Laureate*—'...Raman told me he wished to offer me a permanent position at his institute...As I had no other job, I was willing to accept Raman's offer, if he could obtain the consent of the council of the institute.

'To get this consent he applied all his energy and cleverness; but, alas, he showed also a considerable lack of tact and consideration. He sent out invitations for an extraordinary council meeting—as he explained to me proudly and confidentially— he arranged the mailing in such a way that the Bengali members of the council with whom he was not on good terms would receive it too late.'

What Max Born termed lack of tact and consideration probably stemmed from prejudice as identified by Madan Gopal. Actually, Raman felt disappointed and defeated by a particular event which formed a rigid bias in his mind. It is unfortunate that a person of Raman's stature should have suffered from such blind malice. It gradually took complete hold of his reason. Needless to say, the effects were unpleasant and far-reaching.

It was in 1916 that Raman first came in contact with Meghnad Saha. Even earlier, when still a student Saha had noticed Raman while attending lectures in the association hall. But, then, there was little scope for contact.

In 1916 after Saha and Satyendranath Bose had completed their MSc Raman wished to know if they would be interested in working with him. The enquiry came through a messenger. But neither Saha nor Satyendranath Bose had any interest in the subject Raman was working on— acoustics of musical instruments. These fresh young men just out of the university were fascinated by the latest discoveries like theory of relativity, quantum theory, Bohr's theory etc and were preparing to face the new challenges.

Raman continued his work in classical physics. Meanwhile, Saha had formulated his theory of thermal ionisation which opened up new possibilities in astrophysics. After his return from Europe Saha was offered the Khaira chair of physics. Raman was already there as the Palit professor and head. Soon clashes ensued on very trivial issues. To mention one particular incident, Saha had set up an x-ray unit in room no 12. He found the room locked the next day and learnt that the keys were with Raman. Saha complained about this to Sir Asutosh Mookerjee who often visited the Science College in connection with the Mathematical Society meetings. He offered to mediate by calling both of them over in front of room no 12. The atmosphere in those days was very informal. Sir Asutosh wanted to know who had the keys and asked the room to be opened. Raman unlocked the door. Sir Asutosh handed over the key to Saha but took him aside and advised him to come to terms with Raman if he wished to continue in the Science College.

Shortly afterwards, Allahabad became Saha's venue of work while Calcutta remained Raman's. There were no unpleasant encounters after this. Meanwhile, Raman was elected a fellow of the Royal Society in 1924 and Saha in 1927. In 1930, Raman was awarded the Nobel Prize. A reviewing committee was formed about that time to assess the work of the IIS, Bangalore. Saha happened to be a member of this committee. In a press release Saha observed that the pay structure of the IIS seemed to be rather top-heavy compared to its foreign counterparts. A director of the National Physical Laboratory (NPL), England used to draw £ 1200 per annum while his counterpart in Bangalore drew Rs 3500 per month which amounted to £ 4000 per year. In NPL the lowest salary was £ 240. In Bangalore the research scholars were given Rs 150 per month which was equivalent to £ 120 per year. Saha suggested that salaries for higher posts should be at par with the university grade and the directorship when it fell vacant should be offered to a person of the stature of Sir Raman.

An introduction written by Raman to Saha's treatise on heat did not betray any animosity between the two whatsoever. On the contrary, it expressed appreciation of his work.

In an article to a monthly magazine, entitled *India and the World*, Saha gave a detailed account of Raman's work and also hinted at the controversy amongst the European scientists regarding Raman's Nobel Prize. To quote Saha: 'It was reserved for an Indian to achieve the first success on these lines. This is rather strange, because European writers are never tired of describing the Indians as given over completely to metaphysical speculations and possessed of little practical abilities. Here were the roles reversed—an Indian giving the first practical effect to the theoretical speculation of European savants which they themselves have been unable to verify. The prediction of this effect by other savants does not take away from Raman the great credit which is rightly due to him.'

These terms of tribute show the deep regard and respect Saha had for Raman. Still, it does not rule out the possibility of discord between the two. But it was a clash of opinion between two groups on essentially administrative issues, not a clash on a personal level.

It dates back to the Science Congress session of 1934. As the president of the Science Congress, Saha recommended the formation of an Indian academy of science, on lines of the Royal Society, of London. A Bangalore-based science magazine named *Current Science* took a scientists' opinion poll on the importance of having such an organisation in India. On the basis of Saha's suggestion a special meeting was arranged by the Science Congress general committee (January 3, 1934) that commissioned the academy committee to prepare reports on it. The committee was widely represented by all the Indian universities, societies, government offices and research institutes. Also, five Science Congress representatives were on the committee. Raman as the director of IIS was also there, Louis Fermer was the president, while Saha and Professor S P Agharkar were joint secretaries of the committee. The first academy committee meeting was held at Calcutta on February 11 and 12, 1934. A chain of complexities did however blur the objective of the second meeting. The second meeting was supposed to be held on April 14 and 15 in Calcutta. But Raman's severe criticism of the academy committee at a South Indian scientists' gathering on April 1 at Bangalore and his and his Bangalore colleague Subha Rao's subsequent resignation from the academy committee brought embarrassment to the academy committee members.

On June 16 Raman sent a suggestion that a federation be formed of all the Indian societies like the Asiatic Society of Bengal, the Uttar Pradesh Academy of Sciences, Allahabad and Indian Academy of Science, Bangalore. This was actually an alternative to the plan of the Indian Science Congress.

On June 28 and 29, the third academy committee meeting decided upon adhering to its decision—specially when the decision was being supported by the Indian scientific world. Letters were exchanged once again with a view to compromise which was finally achieved at the seventh meeting, held at Calcutta on November 24, 1934. In the meeting Satyendranath Bose suggested the academy be named National Institute of Sciences of India. The NISI has been renamed Indian National Science Academy (INSA). The academy in Bangalore, however, retained its autonomy. The disagreement involved in forming the science academy has often been interpreted as a personal clash between Saha and Raman. But it is far from the truth.

While defeating Raman's attempts to control the Indian Association for the Cultivation of Science, the intellectuals in Bengal demonstrated their appreciation of excellence by welcoming his student K S Krishnan to the association. Here he made well-recognised contributions to crystal magnetism.



The chapter named 'Oh Calcutta' in the book *Journey into Light* contains some glaring distortion of facts:
a) Meghnad Saha was a candidate for the Mahendralal Sircar professorship.
b) Saha was having a hard time at Allahabad.
c) In Calcutta he had to be content with a mere lecturership.
d) He rushed to Calcutta to manoeuvre Raman's departure.
e) Raman did not receive any help from anybody.

Raman's biographer has justified the first fact in great detail in the last part of 'Oh Calcutta'. In brief he implies that Raman considered Krishnan a more suitable candidate than Saha for the Mahendralal professorship as he found Krishnan to be an active young man on his way up rather than one who had reached a plateau. A few words about Krishnan. He was Raman's associate and the co-author till 1929 of all the research papers on the Raman Effect except one. On Raman's recommendation he was appointed a reader at Dhaka University in 1929. Satyendranath Bose was the professor and head of the department in Dhaka when Krishnan arrived there. Raman may have felt that Krishnan had a very promising future ahead but that should not logically imply that Saha's career had come to a dead end. Surprisingly enough, the biographer himself finds it rather inexplicable, and even admits in the footnote that his presentation of those facts are based entirely on popular hearsay. He himself admits having doubts, hence to give a vestige of credence to it he exploited a popular rumour about the Saha-Raman cold war.

That Saha was a candidate for the Mahendralal Sircar professorship (as per Venkataraman) is puzzling for there is no major evidence proving it, not even letters. The author could not produce any convincing proof in his book. The footnote only mentions that it is based on certain reliable sources—but again does not mention who or what are those sources. Probably he had succumbed to rumours.

The monthly salary for the Sircar professorship was Rs 750. Also, it was not a university professorship. A little application of common sense would tell why it was not a very coveted designation for Saha specially at a time when he was the head of the department of physics, Allahabad University, drawing a monthly salary of more than Rs 1,000. He had built a house of his own in Allahabad, had a large band of brilliant students around him, and he had been the president-elect of the Science Congress. But most important, he had turned down the Palit professorship offered to him, which could have brought him a lucrative sum of Rs 1,500. *Vis-à-vis* these facts it appears rather improbable that Saha would be even mildly interested in the Mahendralal Sircar professorship. Hence the absurdity of the rumour that Saha had a grudge against Raman as the latter had chosen Krishnan for the Sircar professorship.

That Saha was in a very deplorable state in 1933 is again a grossly irresponsible statement. At that time he was deeply involved in research and numerous scientific organisational work. Further, he was able to con-

vince the leading politicians (Jawaharlal Nehru, Subhas Chandra Bose) about the role of science in national planning. Nehru and Bose attended the UP Academy of Science meetings at a time when Saha was emerging as a major force on the national scene. His departure to Calcutta in 1938 came as a great loss for the people of Allahabad.

Another incorrect statement by Venkataraman is that Saha was an ordinary lecturer when Raman was a professor in Calcutta, hence Saha took an intense dislike to Raman. Even though Saha joined as a lecturer in Calcutta, in 1921 he had become the Khaira professor. So, there is no basis behind his nursing a grudge against Raman as a 'mere lecturer'.

That Saha had rushed to Calcutta from Allahabad to manipulate Raman's ouster is yet another erroneous statement. Dr Shyamaprasad Mookerjee was the deciding force and Saha just happened to be there and helped him. The statement that Raman had been driven out of Calcutta is not only highly objectionable but also absolutely untrue as Raman had earlier moved to Bangalore on his own choice as the director, IIS. For all practical purposes he had already left Calcutta. It has been discussed in the beginning of this article how he left his IACS presidentship and under what circumstances.

Raman himself had confided to Sukumar Chandra Sircar, 'assistant to Palit professor', that the reason he had accepted the job at Bangalore was the higher pay and position it offered.

The statement that nobody helped Raman is also incorrect. First Amritalal and then Sir Asutosh gave him a free hand. Sir Asutosh allowed him to use the students and facilities of the Palit laboratory for IACS work. He enjoyed absolute freedom to choose his associates and scholars. He received the highest honours (both British and national) of those times. He received government grants even during the British period. An institute was named after him during his lifetime.

The discussion remains incomplete without the following facts. Saha might have been accidentally involved in the drive to collect life members of IACS during that historic meeting of 1934, but he did not show any interest in the running of this organisation. It was long after he permanently came back to Calcutta that he was interested in the working of IACS. He became the secretary 10 years later in 1944. He was instrumental behind the present shape of the association.

It is unfortunate that Dr G Venkataraman chose the centenary year to make public the rumours he had heard without making the slightest effort to see if there was any substance to them. Raman spent the most creative part of his life in Calcutta—26 long years, during which he received respect and cooperation from all quarters in the city except for one single instance at the end. That unpleasantness Raman brought upon himself by his attempt to capture the IACS and control it according to his whims. While defeating this attempt the intellectuals in Bengal demonstrated their appreciation of excellence by welcoming Raman's student K S Krishnan to the association. Krishnan also spent the most creative part of his life as a professor of the association, making well-recognised contributions on crystal magnetism.

Growth of science in modern times has not always been very smooth sailing. The Indian scenario was further complicated by a number of factors. The prevalent social, political and economic turmoil added to the confusion. On the other hand, by a strange set of circumstances, many outstanding talents crowded the scene. This made the field of research both exciting and difficult at the same time. The history of scientific research or the growth of a scientific institution is incomplete without the personalities involved in it. The pioneer scientists of those days were after all human beings. They had shown the way, created traditions. But it would not be out of place to assume that common human feelings like anger, jealousy or hatred were sometimes reflected in their actions in some way or the other. But it is highly dangerous to distort or misinterpret such clashes. What is needed is an objective presentation of actual facts. Even if there was any difference between Saha and Raman, it need not be blown out of all proportion.

The role of the two academies—the Indian National Science Academy and the Indian Academy of Science—in this unsavoury episode is difficult to understand. How could it allow for publication without proper scrutiny a book which carries unsubstantiated gossip?

This clash has not ended even today. Despite the all-round proliferation of science in India this trend has continued. At present the growth of centralised powers has recreated enclaves of Mughal despotism. Those who are directly involved with it cannot possibly reveal such unpalatable truths, for they have to safeguard their self-interest. For the same reason the historians of science prefer to keep a safe distance from such volatile issues. Thus the modern Indian history of science is like the proverbial iceberg—a large part of it is kept conveniently out of sight. W



Raman spent the most creative part of his life in Calcutta, during which he received respect and cooperation from all quarters in the city except for one single instance at the end. That unpleasantness Raman brought upon himself by his attempt to capture the Indian Association for the Cultivation of Science and control it according to his whims.

Translated from Bengali by Gargi Chattopadhyay

Baidyanath Mukhopadhyay, perhaps the only living student of Sir C V Raman, believes that the Nobel laureate did not actually discover the famous Raman Effect which won him instant entry into science's hall of fame.

ONLY MEMORIES...

PAYAL SINGH

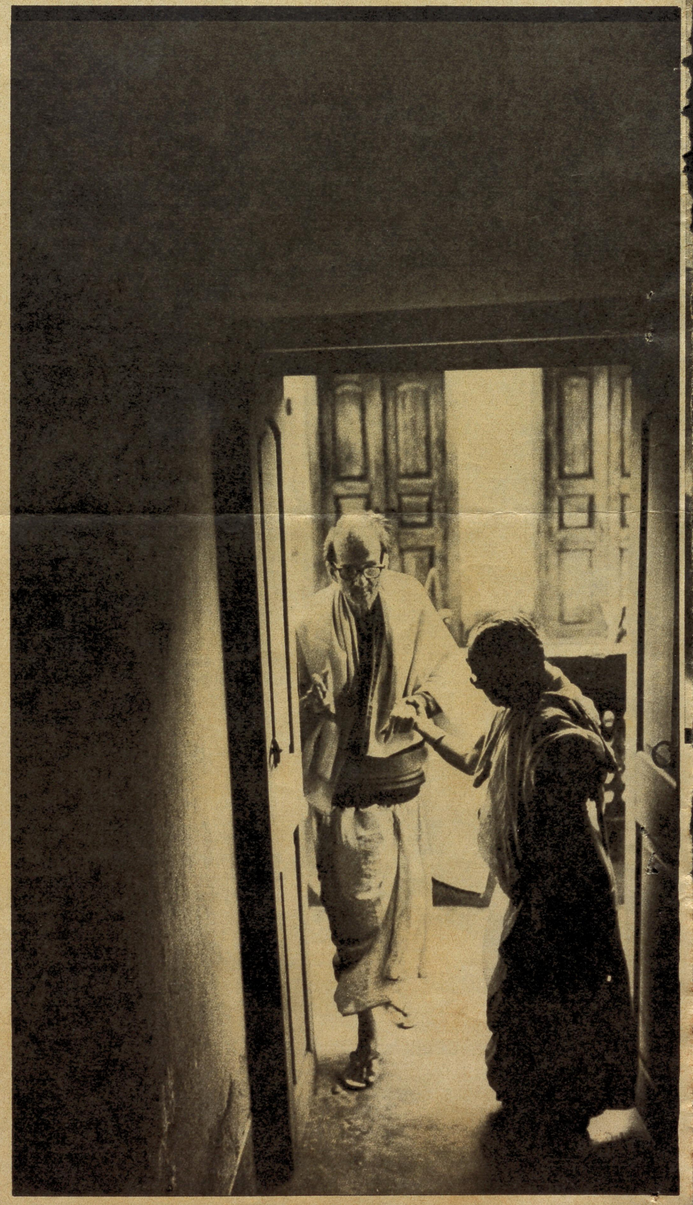
His bespectacled face looks weary. Recuperating from the strain of a heart attack, which left him bed-ridden till very recently, Mukhopadhyay lives a sedate life now. For him it has been a voyage of learning. Though, now, there has been a quiet shift from physics, which he describes as one of the most idea-rich subjects, to philosophy. Leading a retired life, he writes articles on philosophy for Bengali journals.

It was a touching moment. With a walking stick in hand, the 83-year-old scientist staggered up the steps to the dais to receive the gold medal that was being awarded to 409 scientists by Prime Minister Rajiv Gandhi at the birth centenary celebrations of Sir C V Raman in Calcutta. But before he could reach the dais, the prime minister caught a glimpse of his fragile form and rushed towards him with the medal. The audience congregated at the Indian Association for the Cultivation of Science (IACS) applauded. "He almost ran towards me. I was overwhelmed by his good manners," says Baidyanath Mukhopadhyay, who is, in all probability, the only living student of C V Raman, the Nobel Prize-winning physicist.

Recuperating from the strain of a heart attack that he had two years ago, and which left him bed-ridden till very recently, Mukhopadhyay lives a quiet life in Santoshpur, a suburb of Calcutta. He is today steeped in philosophy. "My thoughts have taken a different direction now," he says. The award does not mean very much to him. Though, the sparkling medal, with a sketch of Raman engraved on one side and his own name etched on the other, certainly brings back memories of the celebrated scientist.

He remembers the first time he met Raman during his graduation exam. Mukhopadhyay was then doing physics honours from Presidency College in Calcutta. Raman, who was assigned to take his oral tests was impressed with Mukhopadhyay's knowledge in the subject and invited him to join him, after he had completed his MSc, at the Calcutta University as a 'Palit' research scholar—a prestigious endowment named after the eminent barrister, Taraknath Palit, who had instituted it. As a student, Mukhopadhyay often heard Raman's lectures at the Science Association, which was later known as the Indian Association for the Cultivation of Science. He recalls that Raman always had an attentive audience gifted as he was with high intelligence, a sharp memory and an excellent command over the English language.

Yet, certain memories of Raman evoke an intense disapproval from him. "Raman was unduly proud. That was the whole problem," he says, bringing out an old issue of the *Illustrated Weekly of India* dated June 28, 1970, where the Nobel Prize-winning scientist had declared, 'Raman Is An Adjective'. Raman, who, received the Nobel Prize in 1930 did not really deserve it, believes Mukhopadhyay. "Professor K S Krishnan, a colleague of Raman's, was the real discoverer of what came to be known as the 'Raman Effect', he says and adds that it was Professor Krishnan who first noticed some weak, spectral lines by the side of the original mercury lines. (White light contains all the visible wavelengths of light—colours of the rainbow—and some invisible ones—infrared and ultraviolet. This is revealed by what is known as spectral analysis of white light, ie, the light can be passed through a glass prism or through a spectroscope which sends each coloured component of white light, to a different extent, and so reveals a band of colours, made up of different spectral lines, ranging from red to violet.) Krishnan distilled certain liquids 65 times. Still, the lines would appear. Finally, he took a photograph of those lines and was astonished to see that all the lines were present in the picture. "Krishnan told me he just did not understand why these lines were present. But the moment Raman, who had joined Calcutta University as a Palit professor, saw the lines his face lit up," reminisces Mukhopadhyay.



ACHINTO

Promptly, Raman wrote a paper on it and got it published in the *Indian Journal of Physics*. Apparently, Krishnan and Raman were not on speaking terms for a long time. It was only after Raman received the Nobel Prize that the two reconciled.

"The worst thing about a man of his stature was that he could not appreciate the merit of others in the field of science," points out Mukhopadhyay. According to him, Raman was instrumental in removing two brilliant scientists from Calcutta—Professor S N Bose and Meghnad Saha. "I remember he had kicked their apparatus and treated them shabbily. Their exit was an irreparable loss for Bengal."

There was, however, much about Raman that he admired. "Raman was free from the lure of money," he says. As finance officer in Burma, Raman was approached by a person to help him identify the numbers on some currency notes which had been charred. For more than a week Raman examined the notes under a microscope and managed to decipher their numbers. But when he was offered payment for his service Raman declined it.

A tireless worker, Raman possessed an indomitable spirit and an excellent memory. "He had a detailed knowledge about a wide range of subjects. I remember how impressed we were on one occasion," recollects Mukhopadhyay. An architect, Sirish Chatterjee, who was making an attempt to revive Indian architecture, was addressing a gathering at a function organised by the IACS. Raman, who was presiding over the function, was also asked to speak. Much to the amazement of the audience, they realised that Raman had a detailed knowledge not only of Indian architecture but also of different foreign architectural styles.

Unfortunately, Raman possessed certain characteristics which nobody liked and he was pressurised into leaving Calcutta University, claims Mukhopadhyay. "He joined the Indian Institute of Science, in Bangalore. Here too he was forced to leave," says the octogenarian.

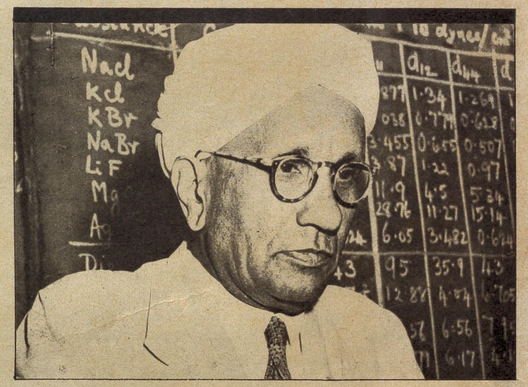
Raman, according to him, greatly upset Indian scientists who were working abroad by calling them carpet-baggers and insinuating that they were trying to woo those in power in order to win the Nobel Prize. And, yet his nephew Subramanyan Chandrashekhar, who won the Nobel Prize for physics in 1983, left for America claiming that the atmosphere in India was not conducive to research work as it was polluted with politics.

An ambitious man, Raman, whose elder son was a barrister, felt that his younger son was going astray. Mukhopadhyay narrates a somewhat incredible story: In a fit of temper, Raman one day lashed out at his younger son, V Radhakrishnan. The beating severely injured him and he remained unconscious for two days. When he recovered, he left for France, where he worked as a sweeper in the dock area. After a while, he got a job as a sweeper in a laboratory. With great curiosity and interest, he watched experiments and asked questions. One day a research worker in the laboratory enquired about his background. When he heard that he was the son of Sir C V Raman, and had left India for personal reasons, the research worker was stunned. Due to his understanding of science, Radhakrishnan was then appointed research assistant.

"Later, he became the director of the Raman Institute in Bangalore and worked on astrophysics," adds the aged scientist. His son accepted his father's failings and apologised to the scientists of Bengal, about whom Raman had stated at a function at the IACS, 'If I had worked with Bengalis only, the Nobel Prize would never have come to the east of Suez'. His son, however, believed that if it had not been for his appointment as a Palit professor in Calcutta University, where Raman did not teach and was liberally financed for research work, he would never have got the Nobel Prize.

The last time Mukhopadhyay met Raman was when he had gone to Delhi for an interview in the early forties and paid his former teacher a visit. A teacher who had inspired admiration and on several occasions, evoked criticism.

"The state of science in our country is more or less static today,"



muses Mukhopadhyay, as Madame Curie's words come to his mind. She had once been invited for the opening of the National Physical Laboratories in New Delhi. Impressed with the infrastructure, she had declared, 'They are indeed very fine. The like of which does not exist in France or any part of Europe, but where are the men to work?' There was just one worker in the whole laboratory at the time. "Even now there is a dearth of serious students," he adds.

And, yet, there are times when those who work hard never receive their due. Mukhopadhyay who had planned to submit a paper on 'diamagnetism' for his doctorate had given it to Professor Krishnan for his appraisal. The professor had left the papers in his drawer for over two years. One day he called Mukhopadhyay and said, 'You have been anticipated. The same work has been published by an English scientist, Stoner, one of the research workers in the field of magnetism.' An angry Mukhopadhyay retorted, 'You sat on it for two years, and now you say I have been anticipated.' Krishnan remained silent.

For Mukhopadhyay, however, it has been a fulfilling voyage of learning. His sons Subrato, a technical assistant attached to Jadavpur University, Calcutta, and Debabrata, "a wizard in electronics" staying in Kuwait, are proud of him. And so is his wife.

Now there is a quiet shift from physics, which he describes as one of the most idea-rich subjects, to philosophy. Leading a retired life, he writes articles on philosophy for Bengali journals.

His bespectacled face looks weary. His journey backwards in time has been long. Memories of those familiar faces are once again tucked away. And the wizened physicist wears his new mantle: a philosopher deeply lost in thought. For, philosophy he believes, is the science of life. W

The last time Mukhopadhyay met Sir C V Raman was when he had gone to Delhi for an interview in the early forties and paid his former teacher a visit. A teacher who had inspired admiration and on several occasions, evoked criticism. A tireless worker, Raman possessed an indomitable spirit and an excellent memory. But, unfortunately, he also had certain characteristics which nobody liked, says Mukhopadhyay.

physicist, full of enthusiasm..... There is really no other Indian physicist who is of his rank..... His European intensity alone would be enough to make Raman suspicious to the average Indian professor. Now Raman, too much aware of his own superiority, likes to make other people feel small in his presence....." Given this combination of traits, he was often misunderstood in spite of his best intentions in the interest of the country.

Raman was a product of his times, a complete scientist in the 19th century mould, comparable only to such famous names as Michael Faraday, Hermann von Helmholtz, James Clerk Maxwell and Lord Rayleigh, known for their insight and ingenuity. Like Srinivasa Ramanujan, he was a self-taught genius who started his research activity in Madras where there was hardly any tradition of scientific research.

It is futile to speculate whether the Raman we know would have come on the scene if he had not gone to Calcutta as the Assistant Accountant-General after topping the Indian Financial Civil Service Examination, though the intellectual ferment in Calcutta those days, not only in science but also in national politics, was certainly of a different order. Calcutta is the city which produced such outstanding contemporaries of Raman as Satyendranath Bose, whose name goes with no less a person than Albert Einstein in the so-called Bose-Einstein statistics, Meghnad Saha who became famous for the Saha ionisation formula, Jagadis Chandra Bose who did his remarkable experiments in biology, and Prafulla Chandra Ray who was not only a scientist of repute but also a man of vision. Ray had a role to play in Raman's rise as a scientist.

Raman himself had once remarked that he would ever be grateful to the Surgeon-General who had not permitted him on health grounds to undertake a journey to England to pursue higher studies. Though his research began when he was barely 17, he did not go abroad till he was 33. Later when he was sailing back to India from England, he made a remarkable observation, from the deck of the ship, on the blue colour of the sea. This led to the discovery of the phenomenon in the scattering of light from media, called Raman Effect.

Raman's times were the heyday of physics. To be ranked along with such names as Ernest Rutherford, Robert Millikan, J. J. Thomson, William Goldschmidt, A. H. Compton, Niels Bohr, Max Born, Paul Dirac and Werner Heisenberg is certainly no mean achievement. The story of Raman as a scientist and his work in Calcutta and Bangalore are well known, but his achievements become even more remarkable when one notes that they were made in colonial India, where opportunities for basic research were practically non-existent. Raman created opportunities for himself; he started his work on light with a heliostat set up on a makeshift platform outside his house, whether it was in Calcutta, Nagpur or Rangoon. The British spent millions to maintain their army in India but their indifference to the growth of Indian science meant that there was hardly any money for research. "And yet," notes G. Venkataraman in his recently published biography, "Raman, and also so many contemporaries of his, did manage to spark the growth of science (physics in particular) in India. As we look back one hundred years after his birth, what we perceive in him is not merely a great scientist but a microcosm of India with all her problems."

Raman was typically Indian. Though he was not religious at all, he never gave up his tuft. In public he always wore a turban and he is reported to have once quipped: "How else could Lord Rutherford have recognised me in the crowded Cavendish Lecture Hall?" His attitudes seem to have sprung from the strong conviction that one need not be born in the West to become a scientist of world calibre.

On record are the remarks of a visiting scientist from Caltech in 1924, who relates how he met a "crazy Indian scientist" who imagined that he was going to discover a quantum effect in light scattering which would win for India the Nobel Prize. Then the scientist ends his anecdote this way: "The unbelievable part of it is that this crazy man does make the discovery (1928) and he does get the Nobel Prize (1930)."

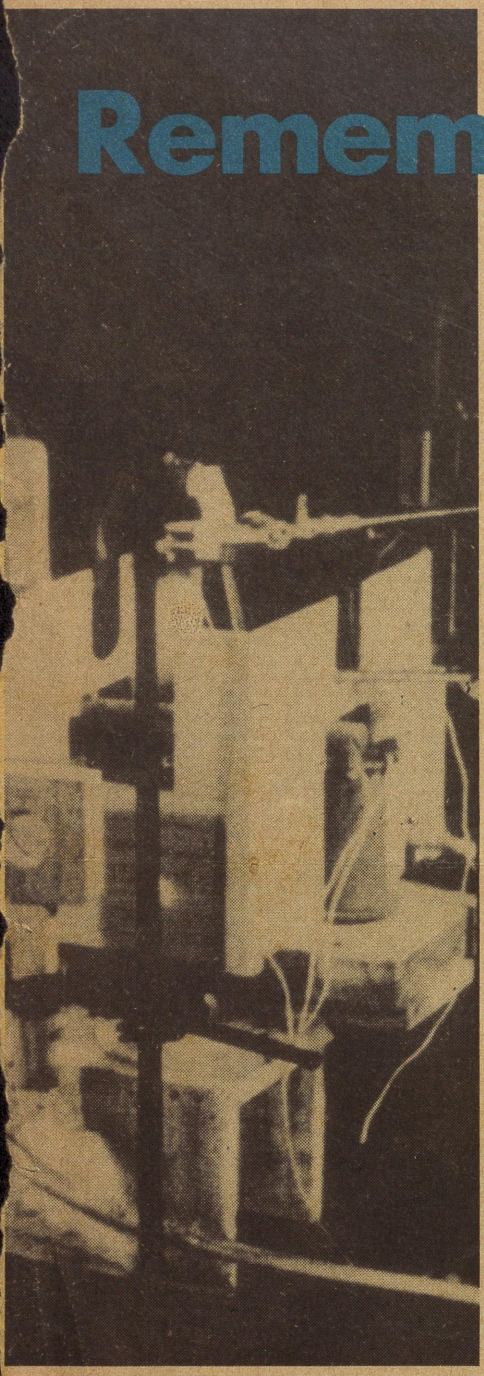
It is also known that in 1925 Raman had written to G. D. Birla that he needed money for an instrument called spectrograph. "If I have it, I think I can get the Nobel Prize for India." Birla's donation of Rs. 1,900 came only a year after the epoch-making discovery which Raman actually made with equipment costing not more than Rs. 500.

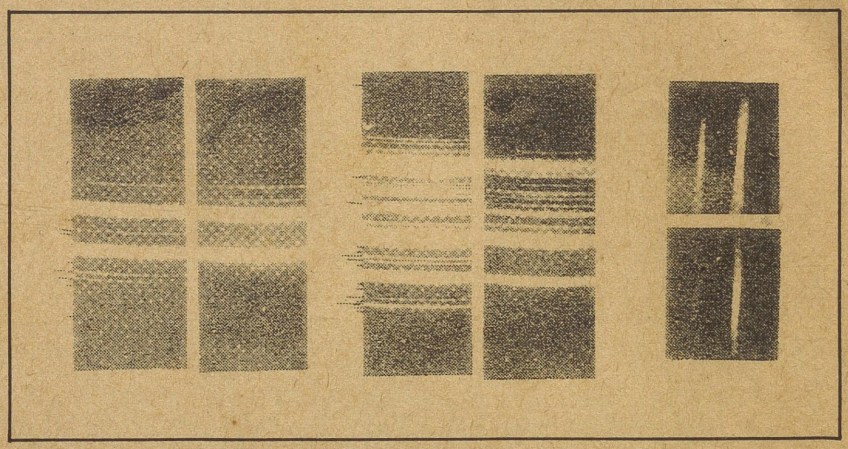
Raman once remarked, while addressing young graduates: " I can assert without fear of contradiction that the quality of the Indian mind is equal to the quality of any Teutonic, Nordic or Anglo-Saxon mind. What we lack is perhaps courage, the driving force which takes one anywhere. We have, I think, developed an inferiority complex. What is needed in India today is the destruction of that defeatist spirit. We need a spirit of victory, a spirit that will carry us to our rightful place under the sun, a spirit which will recognise that we, as inheritors of a proud civilisation, are entitled to a rightful place on this planet. If that indomitable spirit were to arise, nothing can hold us from achieving our rightful destiny."



With German theoretical physicist Arnold Sommerfeld and Krishnan, soon after the Nobel-Prize winning discovery.

Remembering Raman





Sir C. V. Raman in his laboratory; the first spectrograms showing Raman Effect, taken by K. S. Krishnan, one of Raman's students..... the heyday of physics.

Years later, Raman's wife showed this letter, which she had received from a friend in America, to S. Ramaseshan, one of Raman's students now at the Raman Research Institute, Bangalore, and he ventured to ask Raman about it. Raman replied: "Yes, it is true. When I received the (Nobel) Prize from King Gustav, it was a moment of personal achievement. But when I saw the sea of Western faces surrounding me, the only Indian and that too in my turban and close coat, I felt more than ever in my life that I was really representing my country, India. It was a moment of great emotion for me. And, when I turned round and saw that I was sitting under the British Union Jack I realised that India did not even have a flag of her own. That is what triggered the breakdown and I wept without shame."

"Then," continued the letter, "at the banquet that evening Sir Venkata Raman's speech was a masterpiece of eloquence which called forth tremendous applause from the banquet-weary gathering not noted for its responsiveness..... Less appreciative was perhaps the British Ambassador..... who was forced to listen with equanimity to Sir Venkata Raman's reference, brief though it was in passing only, to the congratulatory telegram 'from my dearest friend who is now in jail.'"

This, as one could easily guess, was a reference to the congratulations from Mahatma Gandhi, whom he revered and loved much. In his later days Raman gave much importance to the Gandhi memorial lectures at his institute in Bangalore. He believed that the only way of paying homage to a person he admired was to give him something of what he could do best. Hence the annual lectures on science, a field in which Raman was king.

The incident in Stockholm was indicative of the staunch nationalist Raman was, a facet of his personality which has been largely ignored, clouded as it became in the controversies that surrounded him, first in Calcutta and later in Bangalore. As Ramaseshan said in his inspired address at the Centenary Celebrations in Calcutta, "Raman always found himself at the centre of a storm, which was often his own creation."

Raman could not tolerate mediocrity. In his relentless pursuit of excellence, he would not settle for anything short of the best. He was a man in a hurry, wanting to keep Indian science abreast with the achievements that were being made in Europe, and he felt time was running out.

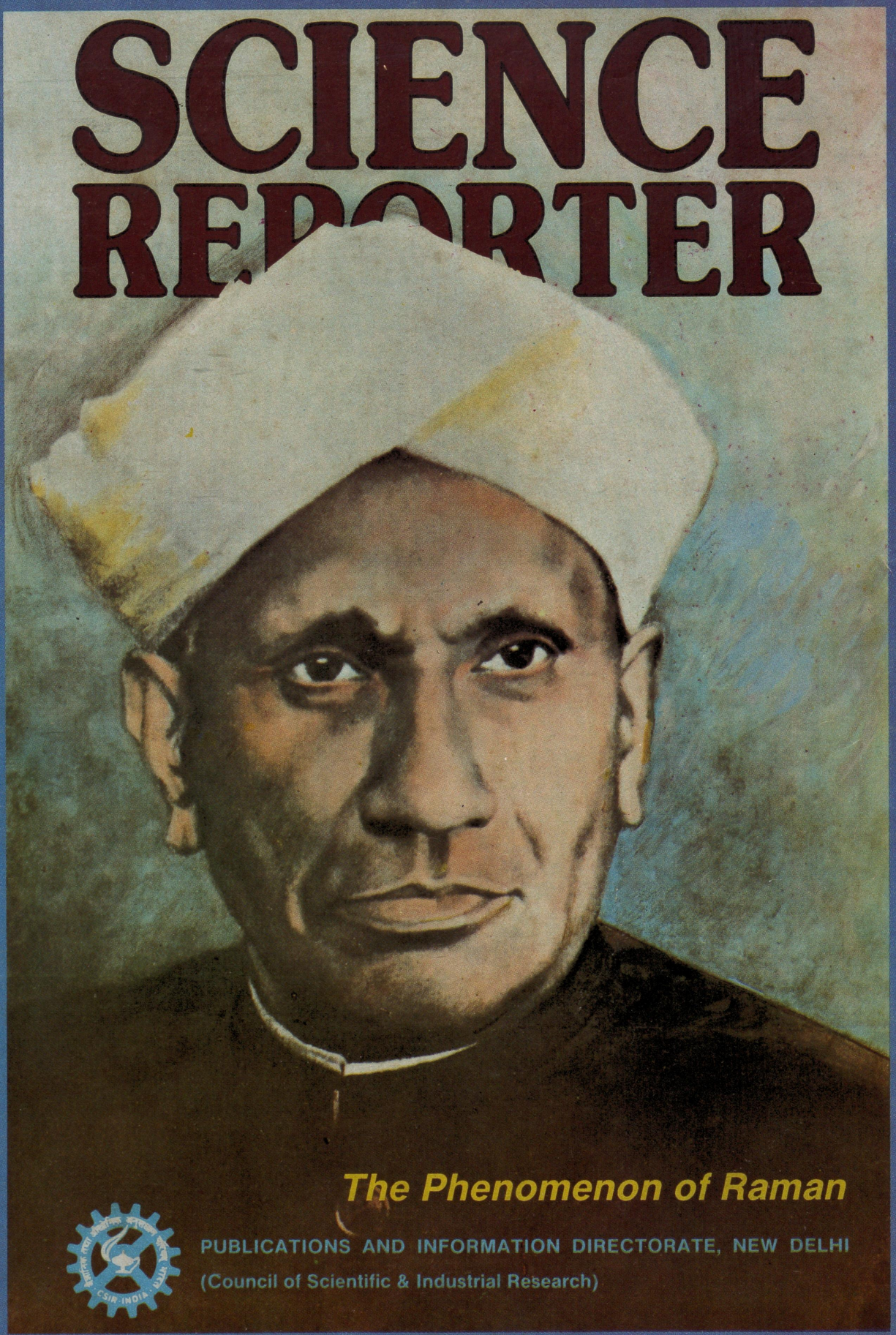
Two-thirds of Raman's life was spent in colonial India. He caused colonial India to be noticed as a scientific centre. His motivations, according to Ramaseshan, were the result not so much of his intense love of science and nature but, as he himself has written, "of the belief in the value of human spirit and the virtue of human endeavour and achievement. And when I read Edwin Arnold's 'Light of Asia' I was moved by the story of the Buddha's renunciation, of his search for truth and of his final enlightenment. It showed that the capacity of renunciation in the pursuit of an exalted aim is the very essence of human greatness."

Raman used to talk of the Mahatma, Christ and the Buddha even on his death bed. It is this inspiration that appears to have driven him in his untiring efforts, in the face of heavy odds, to build a true Indian science, but he could not achieve as much as he could have because circumstances failed him.

Raman's personality was a complex one. He had his shortcomings too. Max Born once said: "Raman is a very able

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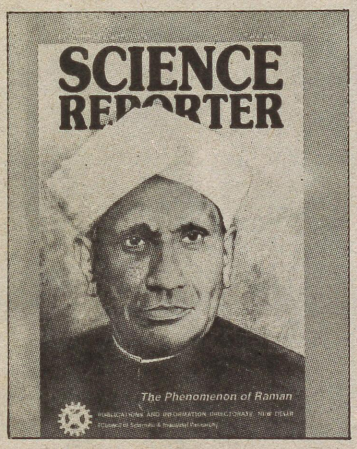
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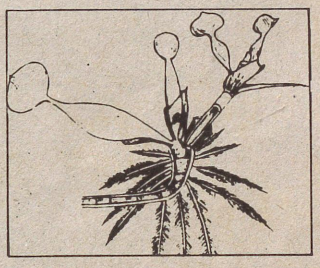
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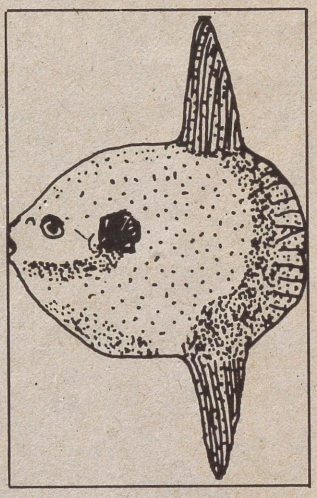
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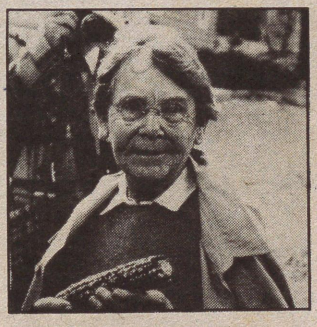
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LETTERS

Fats in our foods

Sir, This has reference to Ishtiaque Ahmad's article **Fats in nutrition and disease** (*S.R.*, August, 1988). The information furnished in the article seems to have been taken from some standard text-books on oils and fats. The treatment is rather too text-bookish for the average reader of your reputed magazine. Instead, the author should have chosen indigenous edible oils and highlighted their specific merits and demerits in our foods and nutrition. Newer oils like palm oil, soybean oil, and rapeseed oil, which we import in substantial quantities, should have been dealt with in a clear and non-technical language.

Of course, we have our own non-traditional and unconventional oils which appear in modest quantities in the market as edible oils. They are corn oil, sunflower oil, nigerseed oil, rice-bran oil, and safflower oil and these oils have earned the stamp of consumer acceptability. In fact, these oils have been proved to be nutritionally superior to the conventional edible oils like groundnut oil, mustard oil, sesame oil, and coconut oil. A suitable coverage should have been given in the article on new and emerging edible oils in our country. The problems faced by the country in edible oils and their role in our foods and nutrition are clearly lacking in the article.

I sincerely hope that *Science Reporter*, a magazine with a commitment to take science and technology to the masses, would be making a signal service to the country by publishing only those articles which have a direct relevance to the country and its population. At the same time, the magazine should avoid drab, repetitive, text-book type of articles to save the readers from avoidable boredom.

G. Azeemoddin
Director
Oil Technological Research Institute
Anantapur-515001

Aluminium utensils

Sir, In his article **Aluminium—the poorman's silver** (*S.R.*, July 1988), V.V.R. Sastry has made a reference to the use of the metal in household utensils.

Evidence has recently been published indicating the relationship between Alzheimer's disease or presenile dementia and ingestion of aluminium. Aluminium was previously believed to be biologically inert, but its toxic effects were found to be accentuated in patients undergoing long-term dialysis who manifest a syndrome—dialysis dementia or encephalopathy—resulting from alum-treated water.

Aluminium is leached out from utensils during cooking of acidic food, or in the presence of fluoride ions, for instance, when brewing tea. Aluminium is normally resistant to corrosion in mildly acidic or alkaline solutions due to the formation of an inert oxide film. The corrosion in the presence of fluoride perhaps results from permeability of the oxide film to fluoride ions, which disrupts the oxide film.

Although the question of neurotoxicity of ingested aluminium in individuals with normal renal function is still unresolved, with the discovery that abnormally high levels of aluminium are present in the plaques of Alzheimer sufferers' brains *(Chemistry in Britain*, April 1987), the cumulative effects of aluminium poisoning need intensive study.

N.G. Wagle
Chartered Chemist
Consulting Chemical Technologist
31 Radheshyam Apts, Juhu Lane
Andheri (West)
Bombay-400058

Diet and cancer

Sir, **Diet and nutrition in cancer prevention** *by* Durga Kumari (*S.R.*, July, 1988) is an interesting article. But there is a contradictory suggestion in this article. According to the author, peas and bread have as fibre-rich food a protective role against cancer. But when the author summarized the practical tips to reduce cancer risk it was suggested that peanuts and bread should be avoided. As bread is the principal food of a large portion of the world and peanuts have high food value, they cannot be avoided.

Besides, it is a known fact that the use of excess chlorine and chlorinated compounds in drinking water should be avoided. But chlorine concentration in river water is high due to the disposal of industrial waste products containing chlorinated compounds into rivers. Unfortunately, chlorine is again added to purify water. Besides, sometimes, halogen is used for repurification of water. All these things gradually increase the cancer risk. Is there a way to avoid this? Because it is not in our hands to control the intake of those chemicals.

Sudip Kumar Ghosh
Sumita Mukhopadhyay
Deptt. of Biochemistry and Biophysics
Kalyani University
Kalyani, Nadia
W.B. 741235

Avoid cancer

Sir, I am a new reader of *S.R.* I liked **"Diet and nutrition in cancer prevention"** in the column "For Her" (*S.R.* July 1988). The article was good, informative and educative. Thanks for publishing other educational and informative articles in the same issue of *S.R.*

I hope you would continue to publish such good and important articles which are useful to children and elders, especially science students like us.

Vidya G. Pawar
C.H.M. College
Ulhasnagar 421003

LETTERS

Diatom not mentioned

Sir, The article **Algae and their utility** *by* D.N. Dhar *et al (S.R.,* July 1988) was interesting and informative. The authors have discussed the different usages of different classes of algae such as Chlorophyceae, Phaeophyceae and Rhodophyceae, etc. However, they have not mentioned one more class of algae known as Bacillariophyceae, or commonly as diatom, which is considered as one of the most economically important groups in the algal kingdom. Diatomite or Kieselguhr, an industrially important material, is obtained from diatomaceous earth or 'Fuller's earth' which is formed by the deposition of the dead remains of diatom. It is useful in coal mines and polishing. It is a good absorber of the highly explosive nitroglycerine. It is also used in insulation of boilers and blast furnaces because of its high resistance to temperature. Diatom has some medicinal value too. Lastly, a significant percentage of the world's oil supply has origin in diatom.

Saibal Chattopadhyay
Deptt. of Botany
Kalyani University
Kalyani-741235 (WB).

Algae and food additives

Sir, Algae and their utility *by* Dhar, Tiwari and Joshi (*S.R.,* July 1988) was interesting, informative, educative. It dealt with medicinal and nutritional values of algae. Alginates derived from them are used as a stabilizer, creaming and gelling agent. However, sodium alginates have some limitation as food additives. They should not be used in acid foods because alginic acid is itself insoluble in water.

Please publish articles related to advanced physico-chemico instruments such as Atomic Absorption Spectophotometer, High Performance Liquid Chromatography, milkometer, densitometer, etc., which are widely employed for the analysis of food stuffs and pharmaceuticals.

J.K. Singh
Jr. Analyst (Food)
Combined Food & Drug Laboratory (Govt of Bihar)
Patna-800007

Poisonous mushrooms

Sir, The article **"Grow mushrooms at leisure"** (*S.R.,* June 1988) was informative. But nothing was mentioned about poisonous and inedible varieties of mushrooms. A few words about them might have been more useful to readers.

Sanjiv Kumar Sinha
Regional Tasar Res. Station
(Central Silk Board)
Dumka-814101.

Perfect numbers

Sir, With reference to the article **'Generating perfect numbers'** *by* Suresh Chandra and O.P. Srivastava Rahul (*S.R.,* June 1988), the formula $N = 2^{p-1}(2^p-1)$ for generating perfect numbers was discovered by Euclid. It has been found that the same formula generates perfect numbers for p = 2, 3, 5, 7, 13, 17, 19, 31, 61, 89, 107, 127 and 257. Further, all the perfect numbers found so far have 6 in the unit places or 8 in the unit places and 2 in the decimal places.

Sujan Sengupta
Dept. of Mathematics
University of Burdwan
Burdwan (W.B) 713104.

A suggestion

Sir, I am a student and regular reader of *S.R.* Every topic discussed in the magazine is educative and informative. Yet I feel the need of another column in the magazine, 'Scholarship Programmes', which will give information on various facilities available in the country for pursuing bachelor's degree, master's degree, doctorate degree, etc. I think this will increase the value of the magazine.

Thanks for publishing **Fluorine : the first hundred years** (*S.R.*, June 1988) by K.C. Joshi, and other interesting articles, viz., generating perfect numbers in the same issue. We want more such type of articles.

Asif Iqbal
Beldanga-742133
Murshidabad (W.B.)

To our readers and subscribers

We are bringing out this issue as a combined Nov-Dec '88 issue to mark Raman Centenary. Consequently current subscriptions would be extended by one issue.

Editor

THE PHENOMENON OF RAMAN

G.H.KESWANI

RAMAN was one of the greatest experimental physicists of the century, a physicist of light, sound and crystals.

Let me quote Lord Rutherford. While presenting Raman the Hughes Medal of Royal Society of London in 1929, even before Raman got the Nobel prize, Rutherford said, "The Raman Effect must rank among the best three or four discoveries in experimental physics of the last decade". The winners of the Nobel prize for work in experimental physics in the preceding decade were : Millikan (charge and mass of the electron and the photoelectric effect), Siegbahn (X-ray spectroscopy), Frank and Hertz (collisions of electrons with atoms), Perrin (Brownian motion), Compton (for the effect known by his name), C.T.R. Wilson (cloud chamber for making visible the track of very small charged particles) and Richardson (thermionic emission of electrons). So, it was quite a thing for the Raman effect to be among the best three or four discoveries.

Indeed, such is the fecundity of the Raman effect that Raman (scattering) figures more often in current experimental research papers than the names mentioned above including Rutherford's, all put together!

Raman was not only an adept experimentalist with light, in the tradition of Young, Fresnel and Rayleigh, but he also fostered an active school of research in our poor country for almost half a century in the grand manner of German spectroscopists of the nineteenth century—Fraunhofer, Bunsen and Kirchoff. His own work extended to some 360 papers and four books. Among Indians, only the chemist, Prof. Seshadri, F.R.S., excelled him in the number of publications, so far as I know. Raman initiated into research nearly 150 students. He was also a charming speaker, holding his listeners spell-bound.

It is difficult to explain his enormous intellectual development. He was taught by himself alone. He dared to publish his first paper in the year 1906 in the *Philosophical Magazine* of London, then the foremost journal of physics, at the age of 18 years, on diffraction patterns due to a rectangular aperture.

Prof. R.L. Jones who had worked in the Cavendish Laboratory, was Raman's teacher in physics at the Madras University, but Raman recollected : "Professor Jones believed in letting those who were capable of looking after themselves to do so.... during the whole of my two years' work for the M.A. degree, I remember attending only one lecture, and that was on the Fabry-Perot interferometer by Prof. Jones himself." Prof. Max Born, a leading physicist of Quantum Mechanics and a Nobel prize winner, talked of the "European intensity" of Raman. Raman himself recalled at the age of 75 years, "I.... do not recollect any time during this long period when I took my mind off from my scientific interests".

Raman was, therefore, a phenomenon, almost in the same class as Ramanujan. Both were completely home-made and self-educated and produced work which will be remembered for centuries.

So, after Raman got the Nobel prize in physics in the year 1930, almost every thinking Indian felt, "We can do it". This spirit must be regenerated, particularly among our scientists.

Raman, the aesthete

Raman loved colour, beauty, form and rhythm in nature He collected thousands of specimens of butterflies. He purchased after personal inspection, hundreds of diamonds of different forms and fire for his studies. He was so much bewitched by the physical properties of the diamond, that at one time every researcher in his laboratories was working on the physics of this simplest of crystal structures—its properties of absorption, birefringence, Faraday effect, fluorescence, luminescence, magnetic susceptibility, photo-conductivity, specific heat, ultraviolet transparency, etc. But, also, no great secrets of nature were thus revealed, although Raman believed that diamond had "characteristic properties of the solid state in a superlative degree".

He wrote extensively on the colours of foliage and flowers, and of gemstones describing the physics of it all, in words which conjure up the colours and lights of Turner's paintings. He gave a theory of the blue of the sea, correcting Lord Rayleigh's conjecture. This was the starting point and inspiration of his main work, on the scattering of light, as Raman told us in his Nobel Lecture in Stockholm on 11 December, 1930.

Incidentally, he regarded Rayleigh as his "teacher". Works of Rayleigh signed by Raman are, I suppose, still kept in the library of the Raman Institute at Bangalore. (I saw them there about ten years ago.)

He made a scientific study of the drums and the violin. His interests and papers in this field, published in *Nature* and the *Philosophical Magazine* of England went so deep that

Mr. Keswani is a Jawaharlal Nehru Fellow and biographer of C.V. Raman. He has a deep interest in physics, applications of mathematics to problems of life, and history and philosophy of science. Address : B6/17, Safdarjung Enclave, New Delhi-110029.

he was invited by the editor of the prestigious German *Handbuch der Physik* in 1927 to write an article for the *Handbuch* on musical instruments. It was a singular honour, a salutation to his experimental work in this field.

Matter, light and their interaction

To understand Raman's work one must know something about the structure of matter and the nature of light. The following description should suffice here.

Matter consists of atoms which can also aggregate into molecules, as the basic bricks of the structure of matter. Each atom consists of a nucleus with a positive electric charge in integral multiples of a unit of charge equal to the charge on an electron which however is negative or opposite (a smaller unit of charge has not been experimentally encountered so far, although fractional charges have been postulated in the quark theory of matter). The nucleus is surrounded by one or more electrons which have the same total electrical charge as the nucleus but opposite in sign. The electrons and nuclei of the atoms, constituting a molecule (such as hydrogen and oxygen in a water molecule), interact in a way such that the atom and the molecule hold together. This model or picture of matter, suffices to explain most of chemistry and much of physics.

The state of the electrons in each atom is determined by the energy of the atom and varies by discrete amounts, i.e., in steps, discontinuously, which are characteristic of each atom. Each of these states corresponds to an equilibrium lasting for a period which may be very short or indefinitely long.

The nature of light is still not fully understood. But an approximate verbal description may be attempted. Light is electromagnetic (em) energy in motion, that is, propagated em energy. It is a travelling electrical field, accompanied by a magnetic field. The intensity of each of these fields varies at any point it traverses, in a periodic fashion like a wave. The fields travel through vacuum with the same constant velocity, and do not require a separate carrier. However, the electromagnetic energy which constitutes light can be absorbed, partly or wholly, by matter in which the same energy is trapped within the atom by a process of change in the state of energy of the electrons. (We need not consider the nucleus for the present purpose.) An atom after absorption of electromagnetic energy, may re-emit this energy, wholly or partly, or it may even part with its own energy and emit more than what it absorbs.

The electromagnetic energy is, however, absorbed or emitted by matter in packets or quanta, not continuously like a flowing stream. Each packet is characterized by just one parameter and that is the frequency of oscillations, υ, of the electromagnetic energy constituting it. (We shall mention later, the spin or the state of polarization of light). The energy of each packet or photon is then $h\upsilon$, where h is a constant (of action, of dimensions energy x time), first postulated in the year 1900 by Max Planck of Germany.

Now consider a highly purified transparent material through which a beam of light of one frequency or colour (monochromatic) is made to pass. Most of the light will pass through but a small amount of it will be scattered in various directions by the atoms and molecules lying in the path of the beam. Lord Rayleigh had studied this phenomenon of scattering in the last century and found that for many liquid scatterers about one-thousandth part of the incident light energy is scattered, and this light has the same wave-length as the incident radiation. (However, the amount of energy scattered varies with the wave-length of the incident light.)

A German physicist, E. Lommel, had shown in 1878 from his theory of scattering, that the scattered light should contain, in addition, some light which combined the frequency of the incident light with the frequency of internal oscillations of the scattering medium but his work received little notice. Another German physicist, A. Smekal in 1923, and H.A. Kramers and W. Heisenberg in 1925 also theoretically predicted that the scattered light would contain other frequencies besides the frequency of the incident radiation and that the changes in the frequencies will be characteristic of the substance of the scatterer. Dirac had theoretically come to the same conclusion in 1927. The resultant frequency was predicted to be the sum or difference of the two frequencies, one external and the other internal. Raman was aware of the work of Kramers and Heisenberg. So were others.

Raman was not only an adept experimentalist with light, in the tradition of Young, Fresnel and Rayleigh, but he also fostered an active school of research in our poor country for almost half a century in the grand manner of German spectroscopists of the nineteenth century

A search was made for these "combination frequencies" by many but without success. In the year 1923, P.A. Ross of U.S.A., using an interferometer of resolving power equal to 360,000, looked for them but failed to detect any shift in the frequencies.

The theory of the Raman effect may now be stated briefly. If $h\upsilon$ is the energy of the quantum of light falling on a molecule, it may interact with an electron of the molecule in the lowest or ground energy state or a higher stage. By a well known formula of Boltzmann, the number of electrons in a lower energy state is more than the electrons in a higher energy state. So an interaction with the ground-state electrons is the most likely, when the electron will have its energy raised by level $h\upsilon$. This disturbed state lasts for a short period of time and there is a high probability that the photon will be ejected with the same frequency (υ) and

energy ($h\upsilon$) by the Rayleigh scattering process. However, if there exists an in-between permitted energy level of the electron $h\upsilon'$ (υ' less than υ), the electron may release energy equal to $h(\upsilon-\upsilon')$, not whole of $h\upsilon$, absorbing energy $h\upsilon'$ itself and remaining at level $h\upsilon'$ above the ground-energy state.

If the incident photon ($h\upsilon$) interacts with an electron in energy state $h\upsilon'$ above the ground state, it will raise the electron to level $h(\upsilon+\upsilon')$ and after remaining in this disturbed state for a very short time, it may fall back into the ground state, emitting a photon of energy $h(\upsilon+\upsilon')$. But because the number of electrons at higher energy levels is smaller, the probablity of a scattered photon of higher frequency $(\upsilon+\upsilon')$ is low.

Naturally, the total energy of all photons of Raman scattering at frequencies $(\upsilon-\upsilon')$ and $(\upsilon+\upsilon')$ will be less than the total energy of Rayleigh scattering at frequency υ. And within the Raman scattering, the emissions at the lower frequency $(\upsilon-\upsilon')$ will have more total energy than those at the higher frequency $(\upsilon+\upsilon')$.

The spectral lines of frequency $(\upsilon-\upsilon')$ are called Stokes lines and those of frequency $(\upsilon+\upsilon')$, anti-Stokes lines. In a laser more electrons can be put in higher energy states within the molecule or the atom, by "pumping" in energy. When this stored energy is released, the laser action takes place in which the light energy emitted is coherent (the waves being in one phase), monochromatic (having almost the same frequency), highly directed (parallel propagation), and concentrated (in a small cross-sectional area with high energy per unit of area). Research with the Raman effect has gone through a renaissance with the use of laser-light.

A word about the polarization characteristic of light or electro-magnetic waves. The electric and magnetic components of these waves at any point lie in a plane at right angles to the direction of propagation or the light-ray path. The electric and magnetic fields themselves stand at right angles to each other in this plane. The direction of the magnetic field of force and the direction of the propagation, then define the plane of polarization of light. The plane of polarization of light from most sources changes irregularly; the light is then said to be unpolarized. As we shall see Raman-scattered light was found to be regular or polarized and this characteristic led Krishnan and Raman to the discovery. We need not go into the details of how the degree of polarization is determined.

Two Indians do it

Let me recall at the outset that the intensities of these combination frequencies are much feebler than even the Rayleigh scattered light. For example, in the case of liquid carbon tetrachloride it is 1/400 and for gaseous oxygen about 1/3300 of the Rayleigh scattering intensity.

The scattering of light by transparent media had been the subject of study in Raman's laboratory since the year 1921. In this year, he himself wrote two papers in *Nature* on the colour of the sea and the molecular scattering of light in liquids and solids. K.R. Ramanathan, then working with Raman, discovered in 1923 that the light scattered even by purified liquids show, what he called, a "weak fluorescence". Similar results were obtained by K.S. Krishnan while experimenting on 60 liquids in 1924. But this research was abandoned in 1925, to be resumed by Krishnan in January 1928, under the guidance of Raman. Soon, the discovery of what is now known as the Raman effect, was made by Krishnan, who kept a diary, related extracts from which are reproduced below :

7th February (1928), Tuesday

Tried to verify the polarization of fluorescence exhibited by some of the aromatic liquids in the near ultraviolet region. Incidentally, discovered that all pure liquids show a fairly intense fluorescence also in the



Dr. K.S. Krishnan

visible region, and what is much more interesting, all of them are strongly polarized...

When I told Professor (i.e., Raman) about the results, he would not believe that all liquids can show polarized fluorescence and that too in the visible region. When he came in up to the room, I had a bulb of pentane in the tank, and a blue-violet filter in the path of incident light and when he observed the track with a combination of green and yellow filters, he remarked, "You do not mean to suggest, Krishnan, that all that is fluorescence". However, when he transferred the green yellow combination also to the path of the incident light, he could not detect a trace of the track. He was very much excited and repeated several times that it was an amazing result. One after another, the whole series of

liquids were examined and each one of them showed the phenomenon without exception. He wondered how we missed discovering all that five years ago.

In the afternoon, took some measurements on the polarisation of fluorescence.

After meals at night, Venkateswaran and myself were chatting together in our room when Professor suddenly came to the house (at about 9 P.M.) and called for me. When we went down, we found he was much excited and had come to tell me that what we had observed that morning must be the Kramers-Heisenberg Effect, we had been looking for all these days. We, therefore, agreed to call the effect "modified scattering". We were talking in front of our house for more than a quarter of an hour when he repeatedly emphasized the exciting nature of the discovery.

9th February, Thursday

When the Professor came from the college at about three, I announced to him the result (for gases), and there was still enough sunlight at the time; he said that it was a first rate discovery, that he was feeling miserable during the lecture because he had to leave the experiment, and that however he was fully confident that I would not let the grass grow under my feet till I discovered the phenomenon in gases...

Evening was busy and when Professor returned after his walk, he told me that I ought to tackle big problems like that and asked me to take up the problem of the experimental evidence for the spinning electron after this work (was over).

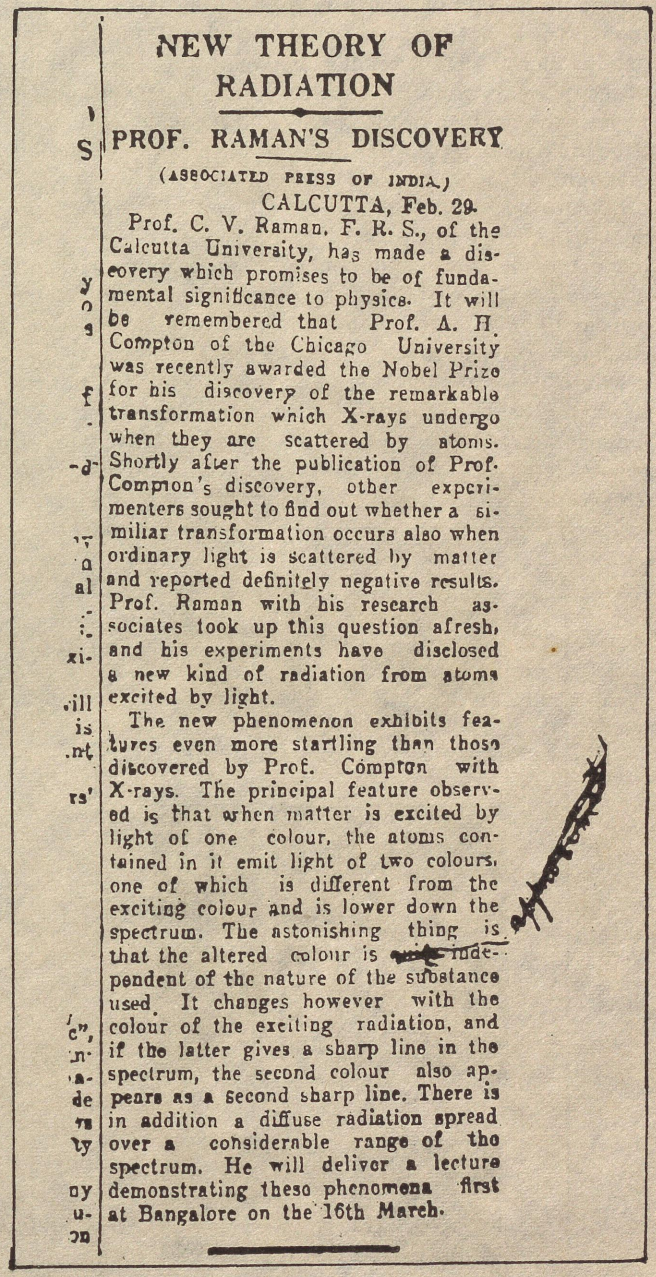
17 February, Friday

Professor confirmed the polarization of fluorescence in pentane vapour. I am having some trouble with my left eye. Professor has promised to make all observations himself for sometime to come.

Apparently, while Raman was checking and confirming the results obtained by Krishnan, a joint letter was drafted and sent for publication to *Nature* on 16 Feb., 1928, which was duly published in its issue of 31 March, 1928 (Vol. 121, p. 501).

On 28 February 1928, Raman announced the discovery to the press and the public.

On 16 March, 1928, Raman delivered an address to the newly formed South Indian Science Association at Bangalore with the title *A New Radiation*. Immediately on return to Calcutta, Raman had this address printed overnight at the Calcutta University Press and reprints of it were posted to thousands of scientists all over the world. I believe that this settled the question of priority of the discovery in favour of Raman. In fact, the Russians, G. Landsberg and L. Mandelstam had made the same discovery (it was later claimed that discovery was made in January 1928) and communicated their finding to the German journal *Naturwissenschaften* on 6 May 1928 (published in the 13 July, 1928 issue, vol. 16, p. 557). The Russians, working on quartz, a solid, had got quantitative results of the change in wave-lengths and a spectrum, which were published with their article. Raman's and Krishnan's work was done on liquids and they had not given any quantitative results in their first letter to *Nature*



NEW THEORY OF RADIATION

PROF. RAMAN'S DISCOVERY

(ASSOCIATED PRESS OF INDIA.)

CALCUTTA, Feb. 29.

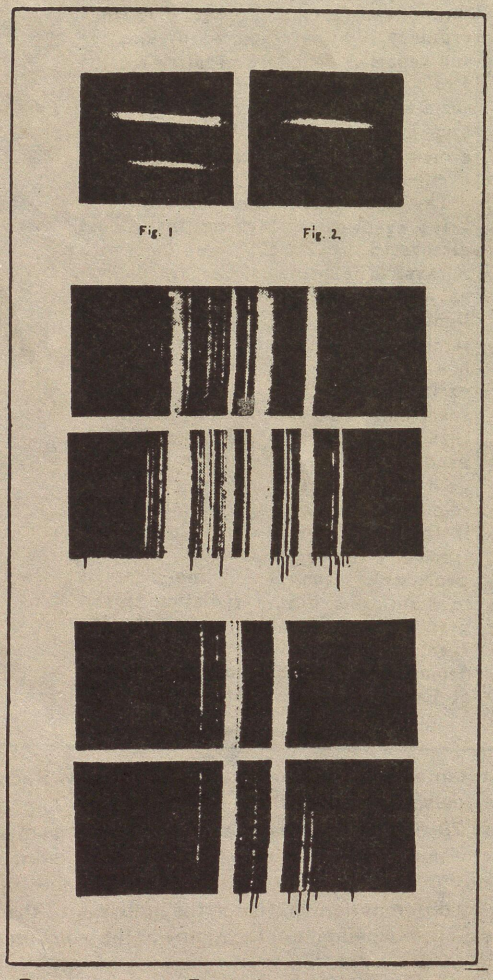
Prof. C. V. Raman, F. R. S., of the Calcutta University, has made a discovery which promises to be of fundamental significance to physics. It will be remembered that Prof. A. H. Compton of the Chicago University was recently awarded the Nobel Prize for his discovery of the remarkable transformation which X-rays undergo when they are scattered by atoms. Shortly after the publication of Prof. Compton's discovery, other experimenters sought to find out whether a similiar transformation occurs also when ordinary light is scattered by matter and reported definitely negative results. Prof. Raman with his research associates took up this question afresh, and his experiments have disclosed a new kind of radiation from atoms excited by light.

The new phenomenon exhibits features even more startling than those discovered by Prof. Compton with X-rays. The principal feature observed is that when matter is excited by light of one colour, the atoms contained in it emit light of two colours, one of which is different from the exciting colour and is lower down the spectrum. The astonishing thing is that the altered colour is ~~quite~~ approximately independent of the nature of the substance used. It changes however with the colour of the exciting radiation, and if the latter gives a sharp line in the spectrum, the second colour also appears as a second sharp line. There is in addition a diffuse radiation spread over a considerable range of the spectrum. He will deliver a lecture demonstrating these phenomena first at Bangalore on the 16th March.

The first Raman spectra (From the paper "A New Radiation") The first newspaper report of the disovery of the Raman Effect (February 29, 1928). It is clear that the observations made with the direct vision spectroscope on 28th could not distinguish the differences in the colour (wavelength) of the new radiation emitted by different liquids. Hence the statement "the altered colour is quite independent of the nature of the substance." The changing of the word "quite" to "approximately" is almost certainly in Prof. Raman's handwriting.

published on 31 March, 1928, although they said that spectroscopic confirmation was available and that modified scattering was demonstrable in the case of high-density gases. Be that as it may, the Russians spoilt their claim, by saying at the end of their article of 6 May 1928, "At the moment it is not possible for us to judge if and to what extent, there exists a relation between the phenomenon observed by us and that for the first time briefly discussed by Raman, because of the brevity of discussion". (In those days the date of receipt of a paper by the journal concerned was not usually published.)

Raman moved on. He wrote another Letter to *Nature*, now in his own name only, on 8 March, 1928, in which he made the following statement : "The preliminary visual observations appear to indicate that the position of the principal modified lines is the same for all substances...." He seemed to believe for some time after the discovery that it was a "new radiation" with a constant shift in frequency, which had been discovered, and that the shift was therefore independent of the material of the scatterer. Indeed, in the report filed by the Associated Press of India, published on 29 February 1928, based on Raman's announcement, the following corroborative line occurs, "The astonishing thing is that the altered colour is quite independent of the nature of the substance used."



The first Raman spectra (From the paper "A New Radiation")

Luminescence and Raman Scattering

THE discriminating characteristics of the new scattered radiation, in terms of the physical ideas current in those days (1920s) were: a decreased frequency of the scattered radiation (initially only decrease was observed) and the strongly polarized nature of the radiation as observed by Krishnan and Raman. The decrease in frequency was known to occur also in the case of fluorescence but this was ruled out because fluorescent radiation was then known to be not strongly polarized.

It can now be said that light scattering in the Raman (Rayleigh, Compton and Brillouin) interactions, might be distinguished from various luminescent processes (which are legion), including fluorescence, by the period elapsing between the excitation of, and emission by a molecule, compared to the period of one oscillation (reciprocal of frequency, $1/\nu$ in sec), of the incident light. This period is of the order of 10^{-14} sec for visible light. The time between excitation and emission has a magnitude of this order, viz. 10^{-14} second, for Raman scattering. But in the case of luminescence it is much longer, being usually in the range 10^{-14} sec to 10^{-10} sec. This is the crucial difference between the two phenomena. Also, Raman excitations are far more universal than luminescence which is markedly exhibited by only some substances.

G.H.K.

However, this astonishing statement of Raman's was corrected in a joint letter written by Raman and Krishnan on 22 March 1928, to *Nature* (third in the series) in which it was stated that "it may be assumed that an incident quantum of radiation may be scattered by the molecules of a fluid either as a whole or in part, etc." Incidentally, there is no mention even at this stage, of so-called anti-Stokes lines of reduced wave-length and increased frequency (or energy), as shown by the theory of Smekal (1923), Kramers and Heisenberg (1925) and Dirac (1927), although Raman was aware of the work of Kramers and Heisenberg, at least. Being a fellow of the Royal Society of London, he should have seen Dirac's 1927 article in the proceedings of the Society.

There is no doubt that the observation and measurements of the modified frequency were most difficult. Krishnan and Raman had available only sunlight and filters, and a pocket spectroscope; that is all. The total cost of the equipment was a lordly sum of Rs. 200/-. Even the mercury-vapour lamp—Alladin's lamp as Raman called it—came after the discovery was made.

Nonetheless, the theory of the effect known to Raman, predicted changes in frequency characteristic of the molecular structure of the scatterer and its internal energy

levels, which varied from substance to substance. As Einstein put it in a message for the Jubilee celebrations of the Raman effect in 1953, this effect for the first time showed experimentally that a photon undergoes a partial transformation *within* matter. The atoms and molecules leave their individual fingerprints, so to speak, on the interacting photons. That is why Raman effect is, perhaps, the best technique for studying the internal structure of matter (leaving other methods behind after the development of the Laser Raman Spectroscopy).

Raman's statement that the position of the modified spectral lines, after scattering was "the same for all substances", cannot be understood. This is not even approximately true, and if it was, the Raman effect would become magic.

I shall return to the role of Krishnan presently but before I do that, I may mention a meeting I had with Prof. S. Chandrasekhar in Chicago in October, 1980. He wanted to know what I had said in my biography of Raman and I told him, among other things, what I have said above. He then went up to one of his filing cabinets and brought out a sealed envelope. He bid me to open it and read some parts which I did. I think, I can say here, that Prof. Chandrasekhar had himself come to similar views regarding the origins of the discovery.

Let us resume our narrative regarding Krishnan's role. After talking about Krishnan's work of 1924, Raman said, in his Bangalore address of 16 March, 1928, "The research was discontinued at the time but was resumed by him [that is, Krishnan] later in the current year (January, 1928). The remarkable observation was made (by whom first ?) that visible radiation which is excited in pure dry glycerine by ultraviolet radiation (sunlight filtered through Corning glass G. 586) is *strongly polarized*". (Words in square brackets are added but italics occur in the original.)

He said in the same address after mentioning award of the Nobel prize to Compton, "I immediately undertook an experimental re-examination of the subject in collaboration with Mr. K.S. Krishnan and this has proved very fruitful in results".

And later, "A more satisfactory proof was, however, forthcoming when Krishnan and myself examined the polarization of this new type of radiation and found that it was nearly as strong as that of the ordinary light scattering in many cases, and is thus quite distinct from ordinary fluorescence which is usually unpolarized."

And at the end, "I owe much to the valuable cooperation in this research to Mr. K.S. Krishnan".

The crucial point is as to who observed the strong polarization of the scattered light, first, and thus set the phenomenon apart from fluorescence which is what it had been considered earlier by everyone involved in it, in Raman's laboratory. Let me quote in this context from the Nobel Lecture of Raman delivered at Stockholm in 1930:

> "Krishnan, who *very materially* assisted me in these investigations, found at the same time that the phenomenon could be observed in several organic vapours, and *even succeeded in visually determining the state of polarization of the modified radiations* from them". (Emphasis added.)

The observations on which the first letter to *Nature* announcing the discovery, were based, used ordinary sunlight. As the above passage shows, Krishnan had the extraordinary ability to determine *visually* the state of polarization using ordinary sunlight (and filters and condensers). The mercury vapour lamp giving an intense beam in a narrow band, came later.

It will be correct to say, therefore, that it was the seeing eye of Krishnan, which made the discovery in Raman's laboratory. It was Raman's experience, imagination, inspiration and status which made it possible for the discovery to be known and immediately acknowledged. And, of course, he had intimations of it and toiled for years over the phenomenon of scattering of light. Raman and Krishnan whose names rhyme, formed an excellent pair, for the observation and understanding of the phenomenon.

It would, therefore, be just to call it Raman-Krishnan effect. I might say here that many knowing authors now attribute the discovery to Raman and Krishnan jointly. I may mention the latest edition of the *McGraw Hill Encyclopedia of Science & Technology* (1986) and *Encyclopedia of Physical Science and Technology,* Academic Press (1987).

So while we remember Raman today, with all our heart, we should equally remember his most able and inspired collaborator K.S. Krishnan. No doubt, as the French historian of science, Taton, has said, both chance and reason play a part in discovery. One is tempted to add that chance meets the prepared mind.

Further reading

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RESEARCH WITH STYLE : The Story of Raman's Study of Light Scattering

S. RAMASESHAN

TO those of us who knew C.V. Raman well, what struck us most was his intense love of and preoccupation with Nature. In one of his lectures he said:

> "The face of Nature as presented to us is infinitely varied; but to those who love her, it is ever beautiful and interesting. The blue of the sky, the glories of sunrise and sunset, the ever shifting panorama of the clouds, the varied colours of the forest and field and the star sprinkled sky at night—these and many other scenes pass before our eyes on the never ending drama of light and colour which Nature presents for our benefit".

In another lecture:

> "The man of science observes what Nature offers with the eye of understanding but her beauties are not lost on him for that reason. More truly it can be said that understanding refines our vision and heightens our appreciation of what is striking and beautiful".

Clearly a different view from Goethe's who wrote that Newton's analysis of the rainbow colours "would cripple Nature's art". Among the natural phenomena that most fascinated Raman were the beautiful coronae and haloes one can see around the sun and the moon when thin clouds come in front of them. This fascination never ceased. In 1910, when he was an Assistant Accountant General in Nagpur. his clerks noticed him at lunch-time studying the solar coronae reflected in a pool of water in front of his office. Later in Calcutta, he was seen often making observations on the lunar coronae, when taking his evening stroll in the *maidan*. I myself have seen him measuring the polarization of the coronae in 1967 in Bangalore when he was 79! Wordsworth's lines on *The Rainbow* come to mind

> So was it when my life began
> So is it now that I am a man
> So will it be when I shall grow old...

Raman stated that purely from the size of the rings, the vividness of the colours, and the polarization characteristics, one can not only estimate the size and distribution of the particles but also deduce whether these are droplets of liquid water, amorphous solidified water or ice crystals. Raman produced these coronae in the laboratory over a wide range of droplet sizes and states that these artificial coronae are more striking in colour than those seen in Nature, as the colours of the latter were diluted by the finite angular dimensions of the sun or moon. He was often up very early in the morning at Bangalore observing the coronae formed around the planet Venus!

It is also remarkable how much science Raman could extract from his study and contemplation of this one phenomenon. I shall give three examples.

Raman's observation of "Speckles" in 1919

Who has not seen the *radiant spectra* — the rays that seem to emanate — when a small intense source of light is viewed against a dark background — the long coloured streamers of light which are seen to diverge from the source in all directions. Raman commenced his detailed studies of this phenomenon around 1918. He noted that when the source is monochromatic, the streamers become spots and faint haloes encircle the source near the outer limit. He connected this phenomenon with the coronae.

Coronae round the sun and the moon are the result of Fraunhofer diffraction by spherical droplets. Raman argued that when radiations diffracted by the individual particles are superposed at any given point of observation, there must be interference. If the particles are distributed at random and execute rapid uncorrelated movements as in a real cloud, these interference effects will be unobservable. The observed intensity would be n times the Fraunhofer diffraction of an individual droplet (assuming n particles of equal size). If on the other hand, the particles occupy stationary positions within the cloud, the interferences between the individual particles must be observable, even if the particles are numerous. For a random distribution of particles, while the most probable resultant intensity would be zero, the average intensity would be nA^2 (where A is the amplitude of the wave scattered by one particle). Hence a point source of monochromatic light, when viewed through a stationary cloud, will exhibit a diffraction corona on which will be "superposed" this interference effect. The net result

Prof. Ramaseshan is Professor-Emeritus at Raman Research Institute, Bangalore. He is a former Director of the Indian Institute of Science, Bangalore and a Jawaharlal Nehru Fellow. Address : Raman Research Institute, Bangalore 560080.

is that instead of a continuous distribution of intensity, one would observe violent fluctuations. The corona, to use Raman's expression must have a "mottled" appearance, each point or "mottle" being like an optical image of the original source produced by the cloud of particles! If the source is one of white light, each point is spread radially into a spectrum (the red being the farthest from the centre) giving the effect of long coloured streamers. The intensity distribution of the spots will be that obtained from the random walk problem, i.e., the Rayleigh law.

Much later, Raman and his (now renowned) student G.N. Ramachandran verified all these deductions in coronae produced by a cloud of lycopodium particles on a glass plate. Incidentally the *mottles* of Raman are the 'speckles' which became prominent when the laser was discovered a few decades later. Raman used to project the halo produced by the colloidal particles of dilute milk and showed that the bright spots (speckles) in the central disk of the corona continually changed, appearing and disappearing in the field of view — an effect due to the Brownian motion of the colloidal particle. In 1919 Raman proposed that the diffracting structures which produced the *radiant spectra* were in the eye. They were in the refractive media of the eye—opaque or transparent particles or small regions with small differences in refractive index in the cornea, the vitreous or aqueous humour or even the lens. These ideas which he put forth, anticipated, in a sense, the modern concepts of twinkling of stars and the speckle formation in telescopes — a connection which was even hinted at by him.

X-ray diffraction by liquids

It is almost certain that Raman's interest in crystal structure determination and in X-ray diffraction arose due to his meeting Sir William Bragg (Senior) in London. Bragg showed him the structure of naphthalene that he had determined. Raman's preliminary calculations showed that the structure shown to him was not consistent with the birefringence of the crystal, and in fact the structure was later modified. This led him on to the idea of using optical and magnetic effects as accessories to X-ray methods for crystal structure determination — concepts which were so elegantly extended and perfected later by his famous student and collaborator K.S. Krishnan.

On his return to India he got his assistants to build an X-ray tube at the Indian Association for the Cultivation of Science. Since the theories of X-ray diffraction by a liquid were quite inadequate at that time, he (with K.R. Ramanathan) developed a satisfactory theory (which A. H. Compton mentions in his book *X-rays and Electrons).*

When a pencil of homogenous X-rays passes through a thin layer of liquid and is received on a photographic plate, there appears in addition to the central spot (given by the undeviated beam) diffraction haloes surrounding the centre. The surprise is that the central disk, i.e., the first peak of the classical diffraction is absent. It was Raman's interest and insight into the halo phenomenon which provided the explanation. He noted that the X-ray case had to be treated differently from the optical one, since the wavelength of the radiation is of the order of the interatomic distance. The discrete structure of the medium would have to be considered when applying the Einstein-Smoluchowski fluctuations theory. These fluctuations occur over distances varying from that between molecules up to that of the containing vessel. If the density were uniform (i.e., if there are no fluctuations), no scattering would occur, as the interference would be complete. Raman showed that this theory could easily explain why liquids scattered X-rays so little at low angles. At larger angles the variations in the intermolecular distances also have to be computed to explain the spread of the halo. This was done from statistical and thermodynamical considerations again using the Einstein-Smoluchowski ideas as the basis.

The classical derivation of the Compton Effect

In 1924 at the British Association meeting at Toronto, Canada, there was a debate on the recently discovered Compton Effect in which Compton and Raman took part. The discussion is of some interest as it underscores the problems that Physics and Physicists faced in 1924, just before quantum mechanics was formulated. In addition to the X-ray scattering of degraded frequency (the Compton Effect), there is an unmodified secondary radiation. Compton had explained this as due to the whole group of electrons in the atom, scattering conjointly. To this view Raman raised the question:

> "If one electron acting alone can scatter a quantum and also all the Z electrons in the atom acting together, then why do we not observe scattering by two, three or more electrons acting together at a time, with their corresponding fractional Compton shifts in wavelengths? To the alternative explanation of the unmodified scattering given by Professors Compton and Jauncey that it represents the scattering by an electron, which the impinging quantum is unable to detach from the atom, the equally pertinent question may be asked, then why is the intensity of this type of radiation proportional to Z^2 and not Z?"

Among the natural phenomena that most fascinated Raman were the beautiful coronae and haloes one can see around the sun and the moon when thin clouds come in front of them

In 1927 Raman's study of the halo again came to the rescue. Using a simplified atomic model in which electrons are regarded as a gas distributed in a spherical enclosure surrounding the nucleus, he showed that the classical wave principles lead directly to a quantitative theory of the Compton Effect

"The problem is very similar to those which continually

Raman's researches on the musical instruments of India

IT was Raman's veiw that although music played an important role in the cultural life of ancient india, the material now available for writing its history is all too meagre. A better method of probing into the development of musical knowledge in ancient India would therefore be a scientific study of the musical instruments which have been handed down as heirlooms for untold generations.

The work of Raman on the musical drums of India is epoch-making and reveals the acoustical knowledge of the ancient Hindus—which is the title of a paper published by Raman. It was Pythagoras who first formulated what makes a sound seem musical to the human ear. If the string of an instrument is plucked (struck or bowed) it not only emits a note having a fundamental frequency, but also produces higher notes. If these overtones are in the ratio of the natural numbers (2,3,4, etc. to the fundamental), the effect is musical, otherwise it is discordant or unpleasant. Scientifically it is well known that percussion instruments as a class can only produce inharmonic overtones and are therefore in a sense only noise makers. Raman's ear however detected that the Indian percussion instruments stand in an entirely different category in that they produce truly musical sounds. He showed that this was achieved by the partial loading of the drum membrane with a firmly adherent but flexible paste. As a consequence the Indian *mridangam* or *tabla* produces a succession of musically harmonic overtones in the same way as any stringed instrument.

The famed stringed instruments of India, the *vina* and the *tanpura*, are of undoubted antiquity and revered as a gift of the gods because their sound is considered closest to the human voice. Their tone exhibits a quality much superior to most "plucked" instruments. Raman made the surprising discovery that certain overtones, which according to acoustical principles should be entirely absent, sing out with great intensity in these instruments. He showed that the violation of what is called the Young-Helmholtz law is due to the curved bridge which the ancient Hindus had cunningly fashioned so that the *vina* (and the *tanpura*) could produce sounds richer in quality, worthy of Saraswati, the goddess of music whose favourite instrument it was.

Raman's acoustical studies were not confined to Indian musical instruments and they extended also to other western ones. While his wife was an accomplished *vina* player, it is hardly known that Raman himself was once a reasonably competent violin player. His mathematical theory of the bowed string and its experimental verification, his theory of how the impact of the hammer produces the exquisite vibration in the pianaforte and his demonstration of the peculiar Wolf Note produced by the violin and cello were all accepted and recognized by the experts of the musico-acoustical world. As a consequence he was invited to contribute to the *Handbuch der Physik* (published by Springer Verlag). This article entitled "Musik-instrumente und ihre Klange" (Musical Instruments and Their Tones) published in this prestigious German encyclopaedia of physics is considered an authoritative one of this subject. Raman wrote the article in English and it was translated into German.

S.R.

(Excerpted from "C.V. Raman and the German connectioin" published in *Science Age,* February 1987)

arise in such optical problems as the theory of coronae..... The answer to it can be given forth by analogy with the known results in optical cases. The resultant of the *Z* vibrations can be divided into two parts, *the first part* is entirely determinate, its amplitude being a function of the angle between the primary and secondary rays which is invariable with time. *The second part* is entirely indeterminate so that neither the amplitude nor the phase can be specified at any given time in any given direction and consequently the frequency is also variable. Nevertheless it is possible to specify the statistical expectation of the intensity of this second the highly *fluctuating* type of secondary radiation."

Compton and Allison in their well known book *X-rays in Theory and Practice* say:

"Raman showed from purely classical considerations that two components must exist....."

and go on to give the theory of the scattering of X-rays by an electron cloud.

"The derivation given closely follows Raman.

It must be mentioned that Compton too derived the same results independently by a different method two years later."

This paper (which was again inspired by his interest in coronae and haloes) is an important one.

He says in it:

".....our expression represents merely a statistical average of a quantity that *fluctuates with time*..... the fluctuations with time of the secondary radiation from the atom involve the corresponding fluctuations in the state of the electrical state of the atom.....

To avoid misapprehension it should be made clear that the fluctuations of the atom we are considering are quite different in nature from the fluctuations contemplated in thermodynamics and kinetic theory. We are here concerned with the fluctuations of the atom from its normal condition under the influences of external radiation."

It was this work which convinced him that light radiation can excite molecules and hence there must exist an optical analogue of the Compton Effect—i.e., interaction between light quanta and molecular vibrations.

The blue of the sea

It is an open question as to how much the books one reads in one's youth influences one's activities in later years. In Raman's case. I think there appears to be a connection. I was able to trace two books which were available in Mr R. Chandrasekhara Iyer's (Raman's father's) house which were *certainly* read by Raman when he was between 11 and 13.

"New Fragments" by John Tyndall published in 1893 contain an article "about common water" which says

> "water of the Lake (of Geneva) is known to be beautifully blue.....Blue is the natural colour of both water and ice. On the glaciers of Switzerland are found deep shafts and lakes of beautifully blue water. The most striking example of the colour of water is probably that furnished by the Blue Grotto of Capri in the bay of Naples.....the walls and water of which shimmer forth a magical blue light.....The bluest of the blue waters are clear and have no detectable suspended impurities."

Popular-Lectures on Scientific Subjects by Hermann von Helmholtz contains some magnificent essays—On Goethe's Scientific Researches. On the Physical Causes of Harmony in Music. On the Relation of Optics to Paintings—essays that must have fascinated young Raman. "On Ice and Glaciers" Helmholtz says:

> "In the depths of the crevasses ice is seen of a purity and clearness with which nothing we are acquainted with in the plains can be compared. From its purity it shows a splendid blue colour like that of the sky, only with a greenish hue.....Their vertical dark blue walls of crystal ice glistening with moisture from the trickling water form one of the most splendid spectacles which Nature can present to us..... The beautiful blue colour they exhibit is the colour of natural water: liquid water as well as ice is blue, though to an extremely small extent so that the colour is visible in layers from ten to twelve feet thickness".

Even from the beginning, Raman's intuition seems to have told him to look for a change in colour in scattering. He and his collaborators used sunlight and the method of complementary filters to detect this change

Put these along with very different views he read later like the following statement by Lord Rayleigh whose every paper Raman is believed to have read:

> "We must bear in mind that absorption or the proper colour of water cannot manifest itself unless the light traverses a sufficient depth before reaching the eye. In the ocean the depth is of course adequate to develop the colour, but if the water is clear, there is often nothing to send the light back to the observer. Under these circumstances the proper colour cannot be seen. *The much admired dark blue of the deep sea has nothing to do with the colour of water, but simply the blue of sky seen by reflection."*

Sir Asutosh Mukherjee (the Vice-Chancellor of Calcutta University) insisted that Raman should definitely go to Oxford for the Universities Congress and this was indeed fortunate. It was on this voyage that he saw the incredible blue of the Mediterranean Sea. He could not believe that the sea could be so blue and so beautiful, nor could he believe that this deep azure was "simply the blue of the sky seen by reflection". Even on board-ship he disproved this conjecture of Rayleigh's noting that when the reflection of the sky by the sea is quenched with an analysing nicol prism

> "the colour far from being impoverished by suppression of the sky reflection was wonderfully improved.... it was abundantly clear from the observations that the blue colour of the deep sea is a distinct phenomenon by itself....."

The rest is history; how, by applying the Einstein-Smoluchowski theory of fluctuations, he established quantitatively that the blue of the sea is due to scattering by molecules—molecular diffraction as he called it; how by laboratory experiments on ice he proved that the blue of the glaciers too arose from molecular scattering. He also showed that molecular scattering was a universal phenomenon in gases, liquids and solids, i.e., irrespective of the physical state of the scatterer.

The scattering of light and the light quanta

In 1921, even before he voyaged to England, Raman had discussed how molecular movements and molecular vibrations could affect the light scattered by a group of molecules (or a cloud of particles). He had concluded that the movements of the molecules would exhibit themselves as a Doppler shift in the frequency of the incident light, that the shift would be dependent on the angle between the primary and scattered radiation and that it should vanish in the exact forward direction. From his vast experience in acoustical studies, he deduced that if the molecular vibrations are anharmonic, combination tones—sum and difference frequencies—may possibly result. (E. Lommel as early as 1878 considered such a possibility!). However, after his visit to England he seemed to be more concerned with understanding the mechanism of scattering. By imagining molecular scattering to take place in a black body enclosure, Raman convinced himself that Rayleigh Scattering must also take place in a discontinuous manner.

> "We must therefore draw the inference either that the Rayleigh law of scattering is not valid or that molecules do not scatter the radiations incident on them continuously. Since the Rayleigh law of scattering is

supported by experiment, at least over a considerable range of wavelengths, it seems more reasonable to accept the latter conclusion, and to infer that the *molecular scattering of light* cannot take place in a continuous manner as contemplated by the classical electrodynamics..... We are apparently forced to consider the idea that light itself may consist of highly concentrated bundles or quanta of energy travelling through space".

This was strong support of the Einstein idea of the light quantum, a point of view not too popular at that time. As Raman said then:

"though Planck's hypothesis of quantum emission, reinforced as it has been by the success of Bohr's theory of line spectra, has passed into general acceptance, Einstein's idea of light-quanta has apparently been regarded as unnecessarily revolutionary in character".

In 1922, Einstein was awarded the Nobel Prize for his services to theoretical physics and for his work on the photoelectric effect. Pais in Einstein's biography says:

Even when the Einstein photoelectric law was accepted, almost no one but Einstein himself would have anything to do with light quanta!

About two years before his death' Nagendra Nath, another of Raman's reputed students told me that in the thirties, [When Raman and Born were great friends (!)] Max Born had told him that he was impressed with Raman's strong advocacy of Einstein's concept of the light quantum in 1921, that he was very pleasantly surprised at Raman's grasping the basic theoretical implications of the Kramers-Heisenberg process, but was truly astounded by Raman's insight in 1921 that Maxwell's field equations would have to be modified to suit the quantum theory!

In the last chapter of his monograph *Molecular Diffraction of Light* Raman writes:

"The belief in the validity of Newtonian dynamics as applied to the ultimate particles of matter has, however, received a rude shock from the success of the quantum theory as applied to the theory of specific heats, and there seems no particular reason why we should necessarily cling to Newtonian dynamics, in constructing the mathematical frame-work of field-equations which form the kernel of Maxwell's theory. Rather, to be consistent, it is necessary that the field-equations should be modified so as to introduce the concept of the quantum of action. In other words, the electrical and magnetic circuits should be conceived not as continuously distributed in the field but as discrete units each representing a quantum of action, and possessing an independent existence".

The words were written in 1921. It is interesting that this programme suggested here of quantizing the electro-magnetic field was commenced by Dirac in 1928 and by Heisenberg in 1930!

The discovery of the Raman effect

After the publication of this monograph in February 1922, the search started.

"Bohr's theory has made the idea familiar that the emission or absorption of light from the atom or the expulsion of an electron involves something in the nature of a catastrophic change. If therefore we wish to look for experimental support for Einstein's conception that light itself consists of quantum units, we must consider those optical phenomena in which obviously no such catastrophic change in the atoms or molecules are involved. The molecular diffraction or scattering of light is obviously such a phenomenon".

Even from the beginning, Raman's intuition seems to have told him to look for a change in colour in scattering. He and his collaborators used sunlight and the method of complementary filters to detect this change. Strangely enough, even in the earliest of these experiments he did with K.R. Ramanathan this colour change was noticed but it was attributed to "a weak fluorescence" caused by impurities. At the insistence of Raman, the liquid was purified again and again but the effect persisted.

Said Ramanathan to me later

"Even in 1923 Prof. Raman refused to believe that this "weak fluorescence" was due to impurities. He said time and again that he felt it was a genuine effect".

The "weak fluorescence" also showed polarization effects but Raman did not, for some strange reason, follow up this important clue as he did later in 1928. In 1924 the "weak fluorescence" was again observed by K.S. Krishnan and in 1925 Raman asked S. Venkateswaran to try to obtain a spectrum of this "weak fluorescence" but no spectrum could be recorded. I have not been able to determine whether this attempt has anything to do with the appearance of the Kramers-Heisenberg paper earlier the same year.

Things came to head in the fall of 1927. Raman, on a holiday in Waltair, worked on and wrote the paper on the classical derivation of the Compton Effect and came back to Calcutta convinced that an "Optical Analogue of the Compton Effect" must exist; and S. Venkateswaran, one of the most diligent of Raman's collaborators made the remarkable observation that the so-called "fluorescence" in glycerine was strongly polarized. This clearly indicated to Raman that the phenomenon could not be the conventional fluorescence—a point of view he had always taken and for which he was seeking proof.

Venkateswaran was a part-time student who could only work after working hours and on holidays. Raman wanted some one to use the sunlight available all through the day, particularly as he himself had lecturing commitments at the University. And so he pursuaded K.S. Krishnan, the best student he had at that time, to get on to these experiments. Krishnan's diary says:

"5th February 1928: For the past three or four days I

have been doing some experimental work..... the last experimental work I did was in the summer of 1926....."

"As Professor says it is not quite healthy for a scientific man to be out of touch with actual experimental facts for any length of time".

Krishnan takes up the problem assigned to him as a dutiful Indian student would, but he is obviously not convinced of the reasons for pursuing these experiments. But within a few days this line of attack led to momentous discoveries.

"...I took up (at the suggestion of Prof.) the general problem of the 'fluorescence'* of organic vapours, rather than the pressing nature of any specific problem in the subject, awaiting experimental solution which usually draws a man to a new field.....studied anthracene vapour. It exhibits strong 'fluorescence'; which does not show any polarization.....".

Raman tactfully suggests changing over first to the study of organic liquids, particularly to that of the polarization of the scattered light and verifying his earlier observations.

"Professor has been working with me all the time. Recently Professor has been studying with Mr Venkateswaran the fluorescence exhibited by many aromatic liquids..... However in view of the fact that anthracene vapour does not show any polarization. Professor has asked me to verify again his observations on the polarization in some of the liquids....."

It is remarkable that within two days of Raman's suggestion. Krishnan confirms the observations of Raman and Venkateswaran in many liquids.

"Tuesday, 7th February.....all pure liquids show fairly intense 'fluorescence' ..... and what is much more interesting all of them are strongly polarized".

Raman verified these observations and wondered why he missed discovering this phenomenon as early as 1923 when Ramanathan had made similar observations.

"He was very much excited and repeated several times that it was an amazing result ..... One after the other, the whole series of liquids were examined and every one of them showed the phenomenon without exception. He wondered how we missed discovering all that five years ago".

Raman then realises that this was the effect he had been looking for, since 1922 (or 1925), a scattering with a modified frequency due to the Kramers-Heisenberg process.

".....Professor suddenly came to the house (at about 9 p.m.) and called for me. When we went down, we found he was very much excited and had come to tell me that what we had observed this morning must be the Kramers-Heisenberg effect we had been looking for all these days. We therefore agreed to call the effect modified scattering ..... He repeatedly emphasized the exciting nature of the discovery."

Raman then asks Krishnan to go back to the study of vapours to the study of the "modified scattering" in them.

"Thursday, 9th February .....Tried ether vapour and it was surprising that the modified radiation was conspicuous..... Professor came from the college at about three.....and there was enough sunlight to see for himself".

and Raman was in a state of euphoria—a man who has at last come to end of a trail.

"He ran about the place shouting all the time that it was a first rate discovery, that he was feeling miserable during the lecture because he had to leave the experiment..... He asked me to call everybody in the place to see the Effect and immediately arranged, in a most dramatic manner, with the mechanics to make arrangements for examining the vapours at high temperatures".

All that remains is to observe it and record it in a spectrograph.

'Tuesday; 28th February. On examining the track with a direct vision spectroscope we found to our great surprise the modified scattering was separated from the scattering corresponding to the incident light by a dark region.... This encouraged us to use monochromatic incident light".

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* The quotation marks are mine. The 'fluorescence' referred to (and the 'weak fluorescence' mentioned earlier) is the light seen from the track of the incident beam through a filter complementary to that in the path of the sunlight incident on the liquid or vapour, and is, therefore, of a colour different from that of the Rayleigh Scattered light.

RAMAN EFFECT— DISCOVERY AND AFTER

R.S. KRISHNAN

WHEN any transparent medium is irradiated by monochromatic light, the radiations scattered by the molecules contain spectral lines of modified frequencies, the difference between the incident and scattered frequencies corresponding to a characteristic infrared absorption frequency of the molecule. Most of the modified lines are of a smaller frequency than the exciting line. There are some relatively feeble lines the frequencies of which exceed the frequency of the exciting line by an infrared frequency of the molecule. In these lines we have for the first time direct experimental proof of *induced emission* (or negative absorption) or radiation by molecules.

The scattered lines are sometimes accompanied by a nebulosity or continuous spectrum extending unsymmetrically on the two sides. The modified radiations scattered at 90^0 exhibit striking polarisation, the degree of depolarisation being different for lines corresponding to different frequency shifts. This scattering phenomenon, which is of a fundamental character, was discovered by Professor C.V. Raman nearly sixty years ago on 28 February 1928 and is since known as "Raman Effect". Due publicity was given to it in the newspapers the next day. Raman submitted a note entitled "Change of wavelength in light scattering" on March 8, 1928 to *Nature* of London. The story goes that this important communication to *Nature* by Raman announcing the discovery of a new effect was referred for comments to a referee who rejected it outright as he thought that such a change of frequency in the scattering process was not possible. Sir Richard Gregory who was the editor of *Nature* took the responsibility on himself and published the same in *Nature* dated 21st April 1928. The effect was observed by C.V. Raman and his student and close associate, K.S. Krishnan simultaneously in gases, liquids, crystals and glasses, thereby establishing its universal character.

Let us trace briefly the sequence of experimental work starting from the summer of 1921 which finally led to the discovery of Raman effect in February 1928.

History of the discovery

In the history of science one often finds that the study of some natural phenomenon has been the starting point in the development of a new branch of knowledge. We have a very good example of this principle in the discovery of the Raman effect which had its origin in the wonderful blue colour of the Mediterranean Sea. Lord Rayleigh had attributed the colour of the sea to the blue of the sky reflected by water. In 1921 Prof. Raman was chosen as one of the delegates to the Universities' Conference held at Oxford. While passing through the Mediterranean Prof. Raman was struck by the deep blue opalescence of its water and conducted some experiments with the aid of nicol prism while on board the ship *S.S. Narkunda* and came to the conclusion that Lord Rayleigh's explanation was not correct. To him it appeared not unlikely that phenomenon owed its origin to the scattering of light by the molecules of sea water.

Immediately after his return to Calcutta in September 1921 he carried out a number of experiments in his laboratory in the Indian Association for the Cultivation of Science with waters collected from different seas. As a result of these experiments he came to the definite conclusion that light molecularly scattered by the oceanic waters played a prominent part in making them look blue. The blue colour of ice in glaciers is also an example of this phenomenon. This was a turning point in his scientific career as the foundation for the discovery of the Raman effect was unconsciously laid during his voyage to Europe. It became evident to Prof. Raman that the subject of molecular light scattering offered unlimited scope for research.

To clarify his own ideas on the subject Raman critically reviewed the results till then obtained in a monograph entitled the *Molecular Diffraction of Light* published by the Calcutta University in 1922. He had clearly indicated in his monograph that there might be experimental observations in light scattering which might require the use of Einstein's photon concept in place of the classical wave theory. As he was convinced that the study of light scattering might carry one into the deepest problems of physics and chemistry, this subject became the main theme of experimental and theoretical activities at the Indian Association by Prof. Raman and his brilliant students.

During the next six years, they established the various laws of molecular scattering of light in diverse media with particular reference to the structure of molecules, the state of matter, pressure and temperature and the phase transition at the critical temperature. Fifty six original

Prof Krishnan, a student of Prof. C.V. Raman, is former Head of the Department of Physics at Indian Institute of Science, Bangalore. At present he is with the Materials Division, National Aeronautical Laboratory, Bangalore 560017.

research papers were published from Raman's laboratory. During the course of these investigations a certain puzzling new phenomenon came to light as early as in 1923 which was pursued systematically to its logical conclusion by Prof. Raman. I shall give below a short history of these developments.

In 1923, K.R. Ramanathan, the oldest and most distinguished of Raman's students discovered that associated with Rayleigh-Einstein type of molecular scattering, there was another and still feebler type of secondary radiation which he designated as "Weak fluorescence" in chemically purified water, ether, methyl and ethyl alcohols, which could not be attributed to any fluorescent impurity. He employed a system of complementary filters and sunlight as a source of radiation. In 1925, K.S. Krishnan, another of Raman's distinguished students, observed the same phenomenon in 65 carefully purified liquids. He also made a crucial observation that the new radiation was partially polarised thus distinguished it from ordinary fluorescence. Towards the end of 1927 Raman himself observed the new phenomenon in optical glasses and in ice.

In January 1928, S. Venkateswaran, a chemist and a Government of India employee working in Raman's laboratory as a part time student outside office hours, made a highly interesting observation that the colour of sunlight (filtered through Corning Glass G 586) scattered by pure dry glycerine was a brilliant green instead of the usual blue and was strongly polarised. The phenomenon appeared to be similar to that observed by K.R. Ramanathan but of much greater intensity, and therefore, more easily studied. The discovery of Compton Effect in 1923 had made familiar the idea that the wavelength of radiation could be degraded in the process of scattering. Raman finally decided to clinch the issue and asked K.S. Krishnan who had been doing excellent theoretical work on mechanical, electrical and magnetic birefringence, to take up the experimental work on the anomalous scattering in liquids and vapours in collaboration with him on a war footing. What followed afterwards is contained in the diary which K.S. Krishnan kept at that time. It gives us an idea of the intense excitement and tireless energy with which the research was pursued and brought to fusion on 28th February 1928. I give below extracts from Krishnan's diary from 5th to 28th February 1928.

5th February, 1928

For the last 3 or 4 days, I have been devoting all my time to "fluorescence". The subject promises to open out a wide field for research, since at present, there is no theory of fluorescence which could explain even the outstanding facts.

Studied anthracene vapour. It exhibits strong fluorescence which does not show any polarisation, when viewed through a double image prism. Prof. has been working with me all the time.

Recently, Professor has also been working with Mr. Venkateswaran on the fluorescence exhibited by many aromatic liquids in the near ultra-violet region present in sunlight and the fluorescence of some of the liquids was found to be strongly polarised. However, in view of the fact that the fluorescence of anthracene vapour does not show any polarisation, Professor has asked me to verify again the observations on the polarisation of liquids.

7th February, Tuesday

Tried to verify the polarisation of the fluorescence exhibited by some of the aromatic liquids in the near ultraviolet region. Incidentally, discovered that all pure liquids show a fairly intense fluorescence also in the visible region, and what is much more interesting, all of them are strongly polarised: the aromatics. In fact, the polarisation being the greater for the aliphatics than for the aromatics. In fact, the polarisation of the fluorescent light seems in general to run parallel with the polarisation of the scattered light, i.e., the polarisation of the fluorescent light is greater the smaller the optical anisotropy of the molecule.

When I told Professor about these results, he would not believe that all liquids can show polarised fluorescence and that in the visible region. When he came in up to the room, I had a bulb of pentane in the tank, a blue-violet filter in the path of incident light, and when he observed the track with a combination of green and yellow filters he remarked "you do not mean to suggest, Krishnan, that all that is fluorescence". However, when he transferred the green yellow combination also to the path of the incident light he could not detect a trace of the track. He was very much excited and repeated several times 'it was an amazing result'. One after another, the whole series of liquids were examined and every one of them showed the phenomenon without exception. He wondered how we missed discovering all that five years ago.

In the afternoon took some measurements on the polarisation of fluorescence.

After meals at night, Venkateswaran and myself were chatting together in our room when Professor suddenly came to house (at about 9.00 P.M.) and called for me. When we went down we found he was much excited and has come to tell me that what we had observed that morning must be the Kramers-Heisenberg effect we had been looking for all these days. We therefore agreed to call the effect modified scattering. We were talking in front of our house for more than a quarter of an hour when he repeatedly emphasised the exciting nature of the discovery.

8th February, Wednesday.

Took some preliminary measurements of the polarisation of the modified scattering by some typical liquids.

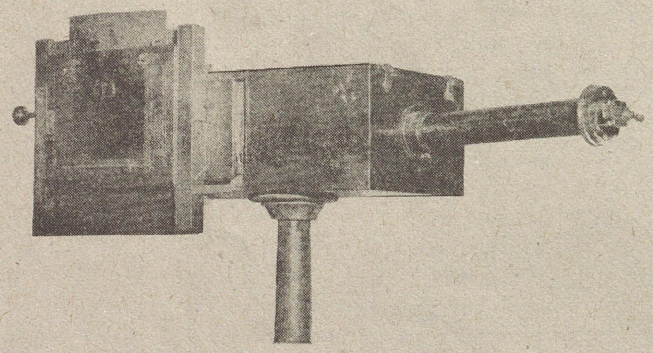
9th February, Thursday.

Set up this morning the long telescope and made preliminary arrangements for observing the effect with vapours. Before the arrangements were completed, Professor left for the college for his lecture.

Extracts from Prof. Raman's address to the South Indian Association in Bangalore on 16th March, 1928

THIS encouraged me to take up observations with a monochromatic source of light. A quartz mercury lamp with a filter which completely cuts out all the visible lines of longer wavelengths than the indigo line 4358 A.U. was found to be very effective. When the light from such a lamp was passed through the bulb containing a dust free liquid, and the spectrum of the scattered light was observed through a direct vision spectroscope, it was found to exhibit two or more sharp bright lines in the blue and green regions of the spectrum. These lines are not present in the spectrum of the incident light or in the unfiltered light of the mercury arc, and are manufactured by the molecules of the liquid.

There has, as yet, not been sufficient time for photographing the spectra from a large number of liquids, or even for measuring the photographs already obtained,



First model of Raman spectrometer designed by C.V. Raman

visual observations have however been made with a large number of liquids. There is an astonishing similarity between the spectra obtained with different liquids. When only the 4358 line was used, most liquids showed in the spectrum of the scattered light a bright line in the blue-green region of the spectrum (about 5000 A.U.) whose position was practically the same for chemically similar liquids such as pentane, hexane and octane for instance.* There was however recognizable difference in the position of the modified line when other liquids such as benzene or water were used. When the 4047 line of the mercury arc was let in by removing the quinine sulphate solution, a second modified line in the blue region of the spectrum was seen with most liquids....

We are obviously only on the fringe of a fascinating new region of experimental research which promises to throw light on diverse problems relating to radiation and wave-theory, X-ray optics, atomic and molecular spectra, fluorescence and scattering, thermodynamics and chemistry. It all remains to be worked out.

I have to add in conclusion that I owe much to the valuable co-operation in this research of Mr. K.S. Krishnan and the assistance of Mr. S.Venkateswaran and other workers in my laboratory.

The line spectrum of the new radiation was first seen on 28th February, 1928. The observation was given publicity the following day.

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* This statement we now know to be erroneous. Prof. Raman and K.S. Krishnan photographed the scattered spectrum using a Hilger Baby Quartz Spectrograph which had only very poor dispersion in the visible region and hence small differences in frequency shifts of Raman lines due to the same chemical bond in different organic substances could not be detected and hence the statement referred to above.

In the afternoon, tried ether vapour and it was surprising that the modified radiation was very conspicuous. Tried a number of others in quick succession without however the same success.

When Professor came from the College at about three, I announced to him the result, and there was still enough sunlight all the time. He said that it was a first rate discovery, that he was feeling miserable during the lecture because he had to leave the experiment and that, however, he was fully confident that I would not let the grass grow under my feet till I discovered the Phenomenon in gases. He asked me to "call everybody in the place to see the 'Effect' and immediately arranged in a most dramatic manner, with the mechanics to make arrangements for examining the vapours at high temperatures.

Evening was busy, and when Professor returned after his walk he asked me to take up the problem of the experimental evidence for the spinning electron after this work was over.

10th February to 15th February

Studied a number of vapours, though a number of them showed the effect, nothing definite could be said regarding the polarisation of the modified scattering.

16th February, Thursday.

Studied today pentane vapour at high temperature and it showed a conspicuous polarisation in the modified scattering. We sent a note today to *Nature* on the subject under the title "A new Type of Secondary Radiation".

17th February, Friday.

Professor confirmed the polarisation of fluorescence in pentane vapour. I am having some trouble with my left eye. Professor has promised to make all observat. is himself for some time to come.

18th February to 26th February.

Studied a number of other vapours.

27th February, Monday

Religious Ceremony in the house. Did not go to the Association.

28th February, Tuesday.

Went to the Association only in the afternoon. Professor was there and we proceeded to examine the influence of the wavelength of the incident light on the phenomenon. Used the usual blue-violet filter coupled with a uranium glass, the range of wavelengths transmitted by the combination being much narrower than that transmitted by the blue-violet filter alone. On examining the track with a direct vision spectroscope we found to our great surprise the modified scattering was separated from the scattering corresponding to the incident light by a dark region.

(S. Venkateswaran was also with them at that time.)

Further work carried out on that day was described by Raman himself in his address under the title "A New Radiation" on 16 March 1928, while inaugurating the South Indian Science Association in Bangalore. The full text of the lecture was subsequently published as a special number of the *Indian Journal of Physics* on 31 March 1928.

The apparatus used by Raman for the discovery consisted of a mirror for deflecting sunlight, a condensing lens, a pair of complementary glass filters, a flask containing benzene, and a pocket spectroscope

The article gave detailed description of all the principal features of the new effect with a photograph of the scattered spectrum of benzene. In this paper Raman had stressed the universality of the phenomenon and its usefulness for obtaining information about molecular structure. 2000 reprints of the same paper were posted to physicists and scientific institutions all over the world. This ultra-quick printing and immediate distribution of reprints so quickly fully ensured Prof. Raman's priority of discovery, for, once announced, many other scientists began to work on it. It was immediately hailed by leading scientists of the world as a very important discovery of a useful method for elucidation of molecular structure.

Thus we see that the discovery of the new type of radiation called universally the Raman effect was the culmination of a line of research initiated by him in 1919 and intensively pursued by him and his collaborators at the Indian Association for the Cultivation of Science during the years 1921 to 1928, that he could not reconcile himself to the explanations of "feeble fluorescence" for the anomalous results; an intuitive perception of a genius that it was something new and his persistence in trying to solve the anomaly resulted in this great discovery of fundamental importance to Modern Physics.

Immediately following the announcement of the discovery, Raman and Krishnan carried out systematic investigations on the new effect and established all the important characteristics of the new effect and its full significance. Their results were published jointly in the *Indian Journal of Physics* and the *Proceedings of the Royal Society*.

Reactions of the scientific community

The importance of Raman's discovery was immediately recognised by Pringsheim in Germany and by R.W. Wood of USA and their subsequent work confirmed Raman's findings. Pringsheim compared Raman scattering with Tyndall scattering, Rayleigh scattering, fluorescence and Compton effect and concluded that Raman scattering was an entirely new phenomenon which enabled one to record the characteristic molecular frequencies more conveniently in the visible region. He called the effect "Der Raman Effect" and the spectrum of new lines as Raman spectrum. He concluded his paper with the following words:—

"With the increasing number of new researchers coming into this field, new problems will show up in increasing proportions. One can state without doubt that through his discovery Raman has opened up a big and completely new field of spectroscopy".

This prophesy has been amply justified by the discovery of new Raman types of excitations using lasers as the source of radiation.

Prof. R.W. Wood sent the following cable to *Nature*. "Prof. Raman's brilliant and surprising discovery that transparent substances illuminated by very intense monochromatic light scatter radiations of modified wavelength and that the frequencey difference between the emitted radiation and one exciting the medium is identical with the frequency of the infrared absorption bands, opens up a wholly new field of study of molecular structure. I have verified this discovery in every particular with improved apparatus which makes it possible to photograph strongest lines in a few minutes.... "It appears to me that this very beautiful discovery which resulted from Prof. Raman's long and patient study of the phenomenon of light scattering is one of the most convincing proofs of the quantum theory of light which we have at the present time".

Dr. L.A. Ramdas who was an old student of Prof. Raman and had taken his Ph.D., degree on the scattering of light on liquid surfaces was working in the Meteorological Department at Karachi at the time of the discovery. He took leave and returned to Calcutta to work on the Raman effect in gases. He was the first to photograph The Raman spectrum successfully with ether vapour. The Raman lines appeared in the same position as in the liquid. He was the first to christen the new phenomenon as "Raman Effect". Based on his work with gases, Ramdas came to the conclusion that Raman effect was probably responsible for the special spectral character and polarisation of the zodiacal light.

Immediately after the discovery of Compton effect in 1923, A. Smekal, an Austrian physicist was working out theoretically the interaction of radiation with matter

quantum mechanically and came to the conclusion that the energy of the incident radiation might be lowered by an amount equal to the energy difference between the normal and excited energy states of the system. He published his results as a note in *Naturwissenschaften* in 1923. The developments that followed the above publication have been summarized by Placzek in his book *Rayleigh-Streuung und Raman Effekt.*

"Encouraged by Smekal's note, Kramers and Heisenberg showed how the origin of this modified scattered radiation can be understood classically, and after this they were able to derive their quantum mechanical scattering formula by combining the correspondence principle with the classical theory of the electromagnetic radiation. The importance of this investigation by far exceeds this field of problems: It was the origin of modern quantum mechanics".

In 1927, Dirac developed a quantum mechanical scattering theory from which he derived the formula for the intensity of scattered radiation. Thus the theory of Raman effect was firmly established one full year ahead of its experimental discovery. These publications were highly mathematical and no experimental physicist working on light scattering took any notice of them. It was only after Raman's independent discovery that the full implications of the dispersion theory came to be recognized. Max Born in a note entitled "Theory of Raman effect" stated that Raman's discovery had been predicted by quantum mechanics in all its entirety and could be thought of as a proof for the same.

The appratus used by Raman for the discovery consisted of a mirror for deflecing sunlight, a condensing lens, a pair of complementary glass filters, a flask containing benzene and a pocket spectroscope, the total cost not exceeding Rs. 200/-. It could also be inferred from the above account that the discovery was not the result of an accident, but was the culmination of seven years of systematic and sustained work carried out with devotion by Raman and his band of students. The achievement is all the more creditable when one considers the fact that scienfitic research in India was not liberally supported by the Government of the day as it is today.

The history of the discovery of the Raman effect teaches us many lessons. Firstly, hardly any discovery appears immediately in its clear and final form. The truth is approached step by step. Secondly, it is the calibre of the scientist that matters for scientific progress and not the provision of very costly equipment. Thirdly, sustained effort in a single field only will ultimately lead to success and fame. Fourthly, great discoveries always appear incredibly simple, but only after some devoted person has made the discovery.

Professor Raman was awarded the Hughes Medal of the Royal Society of England in 1930 and the Nobel Prize for Physics in the same year for his discovery. While presenting the Hughes Medal, Lord Rutherford of Nelson, then President of the Royal Society, made the following observation:

"Sir Venkata Raman is one of the leading authorities on optics, in particular on the phenomenon of the scattering of light. In this connection, about three years ago he discovered that the light's colour could be changed by scattering. This had been predicted theoretically some time before, but inspite of search the change has not been found. The "Raman Effect" must rank among the best three or four discoveries in experimental physics of the last decade. It has proved, and will prove, an instrument of great power in the study of the theory of solids. In addition to important contributions in many fields of knowledge, he has developed an active School of research in physical science in the University of Calcutta".

The Chairman of the Nobel Committee for Physics while presenting the medal to Prof. Raman concluded his presentation speech with the following words:

"Thus the Raman effect has already yielded important results concerning the chemical constitution of substances; and it is to foresee that the extremely valuable tool that the Raman effect has placed in our hands will in the immediate future bring with it a deepening of our knowledge of the structure of matter.

"Sir Venkata Raman, the Royal Academy of Sciences has awarded you the Nobel Prize in Physics for your eminent researches on the diffusion of light and for your discovery of the effect that bears your name. The Raman effect has opened new routes to our knowledge of the structure of matter and has already given most important results.

"I now ask you to receive the prize from the hands of His Majesty".

Russian works

During the same period, Landsberg, who was working in the Institute for Theoretical Physics in Moscow under the guidance of Mandelstam, was carrying out investigations on the scattering of light in solid bodies using a 'Point-O-lite' lamp as a continuous source of illumination. He found that the intensity of scattering in crystalline quartz was directly proportional to absolute temperature. He communicated two papers on the subject to *Zeitschrift fur Physik* on 10 May and 1 August 1927. They were published on 12 July and 18 October 1927 respectively. While looking for a change of wavelength in scattering on the basis of Debye's theory of specific heat. Landsberg and Mandelstam reported on 6 May 1928 the independent observation of a modified line in the scattered spectrum of a crystal of quartz when excited by the radiations from a quartz mercury arc. Their letter, 'Zhuchrift' was published in *Naturwissenschaften* on 13 July. A similar communication was also sent to the *Russian Journal of Physical Chemistry* on 10 May. The frequency shifts arising from Debye's elastic waves should be much less than a wave number and could not therefore be resolved by an ordinary spectrograph. The observed frequency shift was of an entirely different order of magnitude and they explained its appearance in the following words:

'When light is scattered by quartz, some of the infra-red frequencies of the crystal can be excited at the expense of the energy of the scattered light and the scattered quanta; hence their frequencies decrease by the amount of the respective infra-red quanta'.

Although their letter was communicated well over two months after the publication of Raman's detailed paper a reprint of which should have been sent to them also, there is no reference to this (Raman's) paper. They did, however, refer to Raman's two notes in *Nature*, with the following remark; "Whether and how far the phenomenon observed by us is related to that described by Raman in brief, we are not able to decide at the moment as his description is too terse."

No other discovery in science has shown such a dramatic rejuvenation and renaissance as Raman effect. Nearly 47,000 original papers had been published up to the end of 1987 starting from 1928

After attending the Sixth Congress of Russian Physicists on August 5th, 1928, Prof. C.G. Darwin gave an interesting account in *Nature* of the work of Prof. Mandelstam and Landsberg who claimed that "They had independently discovered Raman's Phenomenon, the scattering of light with changed frequency". In reply to the above Prof. C.V. Raman made the following observations in a note to *Nature*.

"It appears desirable in this connection to point out that the existence in the light scattered by liquids and solids of radiations of modified wavelength was established so early as 1923 by investigations made at Calcutta. Dr. K.R. Ramanathan showed (*Proc. Ind. Assn. Sc.*, Vol. 8, P. 190; 1923) that when violet rays pass through carefully purified water or alcohol there is an appreciable quantity of radiations in the green region of the spectrum present in the scattered light. Further studies of the effect in other substances are described by Mr. K.S. Krishnan in the *Phil. Mag.* for October 1925 and by me in *Jour. Opt. Soc. Am.* for October 1927. These investigations were of course well known to workers in this field.

"In a lecture delivered at Bangalore on Mar. 16, 1928 and published on Mar. 31, investigations were described showing firstly, the universality of the effect, namely, that it is observed in the widest variety of physical conditions (gas, vapour, liquid, crystal, or amorphous solid) and in the largest possible variety of chemical individuals (more than eighty different substances); secondly, that the modified radiation is strongly polarised and is thus a true scattering effect; thirdly, that each incident radiation produces a different set of modified scattered radiations; fourthly, that the scattered radiations consist in many cases of fairly sharp lines in displaced positions; and fifthly, that the frequency differences between the incident and scattered radiations represent the absorption frequencies of the medium. These observations established and emphasised the fundamental character of the phenomenon in a manner which any isolated observation with a single substance would have quite failed to achieve. The Russian physicists to whose observation on the effect in quartz Prof. Darwin refers, made their first communication on the subject after the publication of the notes in *Nature* of Mar. 31 and April 21, 1928. Their paper appeared in print after sixteen other printed papers on the effect by various authors, had appeared in recognised scientific periodicals."

It is interesting to note that of the twelve papers published by Professor Raman on the new effect, eight were in collaboration with K.S. Krishnan who himself published four more papers only dealing with some important aspects of the Raman spectra of crystals and on temperature effect and on Raman effect in X-ray scattering. The most crucial communication entitled "A change of wavelength in light scattering" was published by Raman himself. It is also significant to note that after leaving the Indian Association for the Cultivation of Science to take up the post of Reader in Physics in Dacca University in 1929 and later joining the Association as Mahendra Lal Professor of Physics in 1933 when Professor Raman left for Bangalore, Professor K.S. Krishnan completely abstained from carrying on any work in the field of Raman spectroscopy by himself or by any of his students. From the point of view of the progress of Indian Raman spectroscopy this should be considered as a loss.

The account of the early history of the effect would not be complete without a reference to an important theoretical contribution made by G. Placzek in 1934. In this article Placzek had developed the bond-polarizability theory of Raman scattering. Although the quantum mechanical theory of scattering was proposed a year before Raman's discovery, it remained a curiosity for a long time as the numerical calculation of the intensity of scattering required the knowledge of all eigenstates of the scattering systems, viz., a molecule or a crystal, in order to calculate the first and second derivatives of the molecular polarizability. Quantum chemical methods are not so far developed as to make the calculation of such derivatives easily possible. It is in this context that Plackzek's semi-classical bond-polarizability theory became handy for physicists and chemists as a practical proposition.

In order to calculate Raman intensity, Placzek considered the nuclei of the molecules as being fixed. He concluded that the polarizability was a function only of the position of the nuclei, and not of their velocity when the following conditions were satisfied. Firstly, the frequency of the exciting light must be far away from all the electronic transition frequencies. This conclusion excludes the so-called resonance Raman effect which has come into prominence recently. Secondly, the exciting frequency should be large compared to the nuclear frequency of the

electronic ground state. Thirdly, the electronic ground state should not be essentially degenerate.

With these assumptions Placzek derived an expression for the intensity of Raman scattering in terms of the parameters related to the electronic ground state only. The influence of all other states is contained in a term called the polarizability tensor and its derivatives with respect to nuclear coordinates. This tensor is of rank two and is symmetric except for special cases. The main advantage of the polarizability theory was that group theoretical methods could be applied for deriving the selection rules for Raman effect from the symmetry behaviour of the polarizability. On the basis of Placzek's theory all the details of molecular Raman effect could be quantitatively accounted for. His theory is even now finding applications in the derivation of formulae for the hyper, stimulated, inverse, and electronic Raman effect and other nonlinear phenomena which have come to prominence with the development of high power lasers and tunable dye lasers.

Epilogue

Immediately following the discovery, the Raman effect began to be used by physicists and chemists alike for solving a wide range of problems, and many important contributions to our knowledge in physics and chemistry were reported in a short span of five years. This upsurge can be attributed to the fact that the data obtained from Raman spectra depend essentially on the structure of the molecules of the scattering substance. It is thus possible to obtain information of great value to physicists and more so to chemists by a single observation of the Raman spectrum instead of a whole series of difficult experiments in the IR region. More than 2500 chemical compounds were studied by the Raman effect during the first decade following the discovery.

The development of gas lasers in the early sixties and the first successful use of laser radiation as exciter for Raman spectroscopy by S.P.S. Porto and D.L. Wood in 1962 completely revolutionised the practice of Raman spectroscopy. The modern laser radiation is completely monochromatic, completely polarised, perfectly coherent, easily tunable and controllable, of exceptionally high intensity and on negligible divergence. Due to the very small cross-sectional area of a laser beam and the high power densities of light that can be made available at the focal point of the laser radiation as a consequence of its coherence, a new vista of micro-Raman spectroscopic analysis has opened up enabling one to extend Raman effect studies to biological specimens, either by themselves or in solution.

The most startling developments during the laser era were the discoveries of new type of Raman excitations envisaged in the quantum theory of dispersion of Smekal, but not realised in the pre-laser era because of the limitations of the experimental techniques used. They are Raman scattering by polaritons, magnons, plasmons, plasmaritons, Landau levels, excitons soft modes connected with phase transition, and nonlinear processes such as stimulated Raman scattering (SRS), inverse Raman scattering (IRS), hyper Raman scattering (HRS), coherent Raman gain scattering (CRGS), coherent anti-stokes Raman scattering (CARS), coherent Stokes Raman scattering (CSRS), Raman induced Kerr effect scattering (RIKES), surface enhanced Raman scattering (SERS), resonance Raman scattering (RRS), and time resolved Raman scattering (TRRS). No other discovery in science has shown such a dramatic rejuvenation and renaissance as Raman effect. Nearly 47,000 original papers have been published up to the end of 1987 starting from 1928. More than 2,750 papers are published on Raman spectroscopy every year now. A complete Bibliography has been prepared by the author and is expected to be published in due course. Nobody including the discoverer would have ever dreamt about this wide vista of activity of Raman spectroscopy as we witness today.

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Professor Sir C.V. Raman— Reminiscences

R.S. KRISHNAN

IN 1933, five years after the discovery of the Raman effect and nearly two and half years after he was awarded the Nobel Prize, Prof. Raman moved from Calcutta to Bangalore to join as the first Indian Director of the Indian Institute of Science. Immediately a new Department of Physics was created for him where he pursued his scientific activities for a period of fifteen years. I was one amongst the first batch of 8 students, fresh from the University who joined to work under him in July 1933. I was associated with him for the next fifteen years, first as a research scholar and later as a senior member of his academic staff.

Anybody who wished to work under Professor as a regular student had to undergo a searching oral examination in which the candidate's knowledge of fundamentals and capacity for original thinking would be seriously tested. Although he attached some importance to the academic records of the applicant, he always made his own assessment of a student. He never believed in admitting students to work under him on the basis of recommendations from friends and V.I.P's.

Once having selected, the student felt at ease with Prof. Raman. He was kind, generous and large hearted provided the student was sincere and hard working. He had his own ways of developing self confidence and self reliance in his students whom he treated as equals while discussing scientific matters. It was his habit to go round the laboratory every morning, meeting each student, discussing the progress of his work and often suggesting new ideas. He would give free expression to his thought when a new result was brought to his notice. In his public lectures in those days he gave the maximum publicity to the work of his students and would mention their names. All these were a thrilling experience to us as his students who under his influence imbibed intense zeal and enthusiasm for more and more creative research and sustained hard work. Professor Raman encouraged the students to develop capacity for clear talk and exposition. He often used to remark that one should be able to 'think on one's feet'. Whenever an old student called on him, the topic of discussion would always be scientific.

Only his students know Prof. Raman's humanism. He would lend full support to the work carried out by his students. He was always anxious that all the credit for the work should go to the students. As far as he was concerned he guided the students so completely, and looked through every word of the final published paper that any distinction between his work and the student's work ceased to exist.

Raman always encouraged senior students and research assistants who had taken their Doctorates to leave his laboratory and take up responsible positions outside

He would follow the career of the student even after they had taken up job elsewhere. He seldom issued open certificate to any of his students. Whenever any student wanted a certificate to be sent to the authorities where he was seeking fresh employment, Prof. Raman was always very prompt in sending his recommendations directly to the authorities concerned. The students could always count on his support. In this context one is reminded of the famous Malayalam poet Vallathol's poem "Student and Son". As with Lord Siva, the student took precedence over the son in the case of Prof. Raman also. He often gave the following advice to his students whenever they left him for taking up job elsewhere. "Since you are going to earn your livelihood through scientific work, never grudge buying books. You will find an investment in books and journals very rewarding".

The range of Professor's scientific interests was amazing. He had working under him at the same time students of physics, mathematics, physical chemistry, organic and inorganic chemistry and even geology all of whom received his directions and guidance on the

problems on which they were working.

At least once a week there would be seminars where one of the students would report on the work he had been doing, experimental or theoretical, the difficulties encountered by him, the results obtained, etc. During these seminars Prof. Raman would think aloud and one would see and hear his intellectual brilliance and get illuminated and inspired. An interesting incident took place in 1935 to which the author was an eye witness. Parthasarathy, a student of Prof. Raman, was working on the diffraction of light by ultrasonic waves in 1935. While giving a seminar talk on the subject, he described the experimental set-up in detail and also the peculiar results reported by Debye and Sears in USA, by Biquard and Lucas in France in 1932, and Bar in Switzerland in 1933 which could not be accounted for satisfactorily with the well-known theory of Brillouin given in 1922 which was able to explain only the first order diffraction pattern. As soon as Parthasarathy finished talking, Prof. Raman got up and said that the entire phenomenon could be satisfactorily accounted for on the basis that the wave front of the incident light beam which was plane before entering the cell containing the liquid became corrugated due to compressions and rarefactions produced in the medium by the ultrasonic waves traversing it in the transverse direction. He immediately asked one of his students, N.S. Nagendra Nath who had a basic degree in mathematics and who was present in the audience, to work out the mathematical analysis and derive the formula for the intensities of the different orders of the diffraction pattern. Nagendra Nath brought the results of his calculations the next day. Then followed a series of papers of fundamental importance by Raman and Nagendra Nath wherein what is now called the Raman-Nath theory of the diffraction of light by ultrasonic waves was developed. Their treatment not only explained fully the observed facts already reported, but also led to several interesting new ideas and anticipations that were later verified by experiment. This is a typical instance of Raman's flash of intuition which led to the clue for solving a difficult problem using ordinary mathematical logic. In this context, it is worthwhile to quote what Prof. Max Born once said:— "Raman's quick mind leaps over mathematics". While discussing scientific matters with his students he often used to remark "something tells me that this is so and so". He combined in the highest measure the intuitive perception of a genius and the ability of an understanding experimental physicist.

Prof. Raman's first research paper on the "unsymmetrical diffraction bands due to a rectangular aperture" was published in the *Philosophical Magazine* of London in November, 1906, when he was still a student of the M.A. class in his 18th year. The paper was communicated by Prof. Jones of the Physics Department of the Presidency College, Madras, even though there was no acknowledgement or thanks to him. He, being an Englishman, knew that he had not suggested the problem and had nothing to do with the work reported in the paper and that it was his duty to forward the research paper of his student. This kind of rare magnanimity Raman also developed to the highest degree and in his later years he never allowed his name to be added to the papers published by his students based on the work carried out by them even though in many cases the problems would have been suggested by him and many useful tips would have been given by him during the course of the work.

I shall quote what Dr. P.R. Pisharoti, a retired Director of the Institute of Tropical Meteorology and a former student of Prof. C.V. Raman wrote about Raman:

> "On one occasion I was feeling depressed while carrying out an experiment with an X-ray apparatus at the Indian Institute of Science. Professor came in at about 7.00 A.M. and noticed my mood. He asked me the cause of my depression. I replied that a distinguised scientist in the United Kingdom was working on the same problem as myself and that he had a 5 KW X-ray tube at his disposal. He asked me about the power of my X-ray tube. "1 KW, Sir". He said: "That is all; there is a very simple solution. Put a 10 KW brain on the problem", smiled and moved off. He meant what he said. He had supreme self confidence; and more than that he generated it in his students. Time in and time out he would show by precept and example, that ambition, endeavour and courage are the three qualities essential for good scientific work".

Raman believed that it was essential for the Research Assistants and students to live close to the place of work so that they could devote maximum time for work. When he was given permission to work outside office hours in the Indian Association for the Cultivation of Science at Calcutta in 1907 while working as a Finance Officer of the Government of India, he himself took up a house adjoining the Institution, though it was not a desirable locality and had a door opened between his house and the Association so that he could reach the Laboratory informally for work at any time, by day or by night. After assuming the duties of the Director of the Indian Institute of Science in Bangalore he was the first Director to insist upon providing accommodation in the premises for the Research Assistants in preference to the supporting subordinate staff. Each research student was given a key of his room which enabled him to come and work in the Laboratory outside office hours and at night. Prof. Raman was the Central Sun around which the whole institution revolved and from which each part received its energy.

Prof. Raman used to admit students of different disciplines, physics, mathematics, chemistry, geology, etc., to work under him as research scholars. This has paid rich dividends. The development of the Raman-Nath theory was a typical example how a pure mathematics student like N.S. Nagendra Nath, who was working under Raman in 1935, was able to solve the problem of the diffraction of light by ultrasonic waves once the basic physical principle of the formation of the corrugated wave front flashed to Raman's quick mind and he wanted the resulting mathematical analysis to be worked out.

S. Venkateswaran and P. Krishnamurthi who were basically post-graduates in Chemistry were working as part time students outside office hours in Raman's laboratory at Calcutta at the time of the discovery. S. Venkateswaran along with A.S. Ganesan and S. Bhagavantam studied the Raman Spectra of a series of homologous related organic compounds of similar structure. Their work led to the important conclusion that each chemical bond could be identified by a characteristic Raman frequency. They along with the group under K.W.F. Kohlrausch at Graz were the pioneers in establishing the Raman finger-print for each and every chemical bond. P. Krishnamurthi was the first to investigate systematically a series of inorganic compounds, such as carbonates, nitrates, sulfates, etc., and established the characteristic internal vibration frequencies of various chemical radicals and the way in which they were influenced by the metal ion.

Prof. Raman was very fastidious regarding the upkeep of equipment in good condition and he could not tolerate any student found handling the apparatus rashly. He had a member of his academic staff always to be in charge of apparatus and facilities of the laboratory. In Calcutta it was Ashutosh De, while at the Bangalore Institute, it was C.S. Venkateswaran in the beginning and later myself. At the Raman Research Institute it was one Padmanabhan. One of the research students working on the Raman Spectra of uranyl nitrate had obtained some new results. While measuring the spectrogram he got the screw of the measuring microscope jammed and the matter had to be reported to Professor Raman who got terribly annoyed and enquired from C.S. Venkateswaran whether the student was given proper instructions for using the micrometer. The latter's answer was in the affirmative. Prof. Raman asked the student to explain how he got the instrument jammed. On being told by the student that he wanted to find out how far the screw would go and in the process it got jammed. The student concerned was immediately asked to leave the Department even though he had done some good work.

Prof. Raman could be placed on a par with two other world renowned physicists : Lord Rutherford of Cambridge and Prof. Niels Bohr of Copenhagen

Since 1928, it was Raman's policy to publish all the contributions from his Laboratory in Indian Journals, instead of in well-known journals published from abroad. Of course, he continued to contribute the first announcement of important discoveries in the correspondence columns of *Nature*. While at Calcutta, papers from Raman School appeared almost exclusively in the *Indian Journal of Physics*. From 1934, the papers from his Laboratory at the Indian Institute of Science and later at the Raman Research Institute appeared in the *Proceedings* of the Indian Academy of sciences, Bangalore which he started and of which he was President till his death in 1970. He thereby raised the prestige of these journals. He used to encourage the students to get reprints of their papers and send them freely to scientists working in the respective fields abroad. This ensured maximum publicity to the work of his laboratory. The notable feature of the Academy was the unfailing regularity with which the *Proceedings* were issued on the last day of every month during the 35 years of Raman's association with the Academy. This is entirely due to Professor Raman's initiative and hard work.

Well over one hundred and fifty young men—mathematicians, physicists, chemists and geologists, etc., had their first training in research under Prof. Raman. Many of his past students occupied important positions all over the country as Professors, Readers or Lecturers in Universities and colleges or members of the scientific services of the Central and State Governments in India. Quite a large number of his students continued to make valuable scientific contributions after they left his laboratory. However, it was also not uncommon that some students who had done extremely well when they were with him, were never heard of again in the scientific field once deprived of his guiding spirit.

Raman always encouraged senior students and research assistants who had taken their doctorates to leave his laboratory and take up responsible positions outside. In this respect he followed the principle adopted by prestigious American universities of encouraging post graduate students to take up faculty positions in other Universities after they had obtained their doctorate degrees. Very few students of Raman had continued to work in his laboratory for more than five years. Even K.S. Krishnan, who joined as a research student in 1924 and was one of Raman's distinguished students and a close collaborator in the experiments leading to the discovery of Raman Effect, had to take up the post of Reader in Physics in the Dacca University in early 1929. I was an exception to this rule. I was associated with him for a period of fifteen years first as a research student, later as a seniormost member of his Academic Staff, and finally succeeded him as Professor and Head of the Department of Physics when Prof. Raman retired from the Indian Institute of Science, Bangalore. Prof. Raman often suggested to me to take up more lucrative positions outside the Institute.

Prof. Raman discouraged the practice of post doctorate students going abroad for further training. One of his students who was with him for just over ten years expressed a desire to take leave for a couple of years to take up a fellowship under a professor in one of the American universities. Prof. Raman was very much against it and when the candidate persisted he was asked to resign and leave the Institute permanently. Of course, he is much better off for that now. But after this incident Professor got disgusted with the behaviour of his students not heeding to his advice. He immediately asked the remaining five

research assistants and students who had all taken their doctorate degrees to leave. He got them all good positions in different Institutions in India.

Unlike the practice adopted by many Indian Professors and senior scientists, whenever Raman shifted from one laboratory to another he seldom took any of his old associates with him. When he shifted his activities from Calcutta to the Indian Institute of Science he started his researches with a fresh band of students. The same was the case when he moved from the Indian Institute of Science to the Raman Research Institute in Bangalore in 1948.

There was scarcely any university or cultural organisation in India during Raman's hay-days which had not in the past invited him to give lectures on scientific and other topics. Raman's exposition of any subject was masterly and most impressive. He had a good command of the English language. He started from the fundamentals and built up as he went along in a masterly way. His popular lectures on scientific subjects, always delivered extempore, attracted large audience and were listened to with rapt attention. He could talk on even the most obtruse subject in a simple and lucid way so that even a lay man could easily follow the same and go back satisfied.

According to Prof. Raman, the principal requisite for success in scientific research is not the maturity of knowledge associated with age and experience but the freshness of outlook which is the natural attribute of youth. The principal function of the older generation of scientific men is to discover talent and genius in the younger generations and to provide ample opportunities for free expression and expansion. Intellectual beauty is indeed the highest kind of beauty. Science is the fusion of man's aesthetic and intellectual functions devoted to the representation of nature. It is therefore the highest form of creative art.

Prof. Raman could be placed on a par with two other world renowned physicists: Lord Rutherford of Cambridge and Prof. Niels Bohr of Copenhagen. All the three had trained a large number of students who in turn have become world famous in the scientific field. Both Raman and Rutherford were outspoken, outgoing and direct. They liked physics, their experiments were simple, and they described their work in simple and concise language. Both had a loud and booming voice. Both were in the habit of making decisions easily and firmly. They could be rude and unreasonable at occasions. Both were fond of making disparaging remarks about theoreticians who were very much attached to formal mathematics.

Both Raman and Niels Bohr believed that truth and clarity are complementary. They were capable of enormous enthusiasm for a promising new idea in physics. They regarded mathematics as an important tool but never as an end itself. They were not deflected by unimportant details but gave painstaking attention to detail when it mattered.

The similarities in the behaviour of Lord Rutherford, Prof. Niels Bohr and Prof. C.V. Raman were responsible for the mutual respect they had for one another. In the inaugural address to the South Indian Science Association at Bangalore on March 16, 1928 announcing the discovery of a "New Radiation", Raman had used the first person singular only once in the whole lecture. He was taught this modesty by the late Lord Rutherford who had said that a true man of science simply would say that he found something and if somebody helped him, he would say that so-and-so helped him. The lecture delivered at Bangalore, being of a historical nature, was meant to convey what Prof. Raman really felt.

Subjects like colours of flowers, origin of minerals and gem stones, plumage of birds, butterflies, the blue of the sky and the ocean and other natural phenomena were his primary concern

All the three Nobel Laureates were very fond of meeting their old students at least once a year to exchange scientific ideas. Prof. Raman, on his part, used the Annual Meeting of the Indian Academy of Sciences to meet all his past students who were still active in research for mutual discussion of scientific problems. Prof. Raman used to enjoy this annual treat, while his students got inspiration from his brilliant Presidential Addresses and scintillating after dinner speeches. During the year 1936-37 when Prof. Raman was passing through troublesome days in the Indian Institute of Science, it was said that Lord Rutherford had written to the Viceroy of India to ensure that under no circumstances should Raman's scientific activities be jeopardized by any action which the Governing Council of the Institute might take. Sir Mirza Ismail, the then Diwan of Mysore, was also responsible for insisting on Professor Raman's retention in the Institute at least as Professor and Head of the Department of Physics. This noble gesture had enabled Prof. Raman and his associates to continue to make notable scientific contributions in the field of crystal physics, X-ray diffraction, lattice dynamics, Raman and Brillouin spectroscopy, the physics of diamond, etc., thus bringing further recognition to the Indian Institute of Science in the world of science.

Prof. Raman was an egotist to the core and he took real pride in being a self-made man. He owed no man—European or Indian—any debt of gratitude for his achievements as one of the leading scientists of the world. His only inspiration was the *Collected Papers* of the Rayleighs (father and son) and his own ever enquiring mind and his intuitive perception of the deepest concealed secrets of Nature. Nature was his object of worship and inspiration. Subjects like colours of flowers, origin of minerals and gem stones, plumage of birds and butterflies, the blue of the sky and the ocean and other natural phenomena were his primary concern.

Prof. Raman was very frank in expressing his views. He

was one of those rare courageous men who would call 'a spade a spade'. He was not tactful enough in administrative matters and in this process he created enemies for himself. Most of his students were "Yes men", an epithet given by an American professor (Visiting Professor in the E.C.E. Department of the Institute) who was staying in the Raman Research Institute campus. Very few of Raman's students had the courage to warn him about the consequencies of some of his administrative decisions.

He was a man of emotion and he could violently get angry. In this connection I would like to narrate a personal experience. One of my students, N. Krishnamurthy had published a paper in the *Indian Journal of Pure and Applied Physics* in 1966, on the lattice dynamics of caesium bromide crystal using Born's theory of lattice dynamics. Prof. Raman could not see eye to eye on this subject with Prof. Max Born and they became bitter enemies. A request for a reprint of this paper went inadvertantly to the Raman Research Institute. This brought to his notice the existence of such a publication from any laboratory at the Indian Institute of Science, and the fact that *my* students were working on lattice dynamics of alkali halides using Born's theory and explaining the observed spectroscopic data of such crystals satisfactorily. This he disliked very much. A few days later I went to meet Professor in some other connection. He was so angry and annoyed with me that he abused me profusely. I coolly pocketed what all he said and quietly walked out of his room in the Raman Research Institute.

We have a right to be proud of Chandrasekhara Venkata Raman. He was a graduate of the Madras Presidency College. He got no training in foreign laboratories or universities. He was the son of a poor school-master. He did not have a posh laboratory and modern ready made equipments to work with. He did everything from what he got in India and what his assistants fabricated and yet earned many laurels including the Hughes Medal of the Royal Society of London and the Nobel Prize in Physics for a fundamental and far-reaching discovery recognized as great by the whole world of science. This is not just foolish insular pride but an argument for greater confidence in ourselves (Indian) than that generally prevails now.

Sir C.V. Raman himself was grateful to Calcutta and the big men of Bengal. He always remembered and said that his scientific work was made possible only through the greatness of Dr. Mahendra Lal Sarkar who founded the Indian Association for the Cultivation of Science in Calcutta. No less was Raman's gratitude to Sir Asutosh Mukherjee who it was that pursuaded Raman to give up his post in the Finance Department of the Government of India and devote himself entirely to the pursuit of science under the aegis of the Calcutta University. But for this C.V. Raman would have respectfully retired as a faultless Accountant-General.

May the example and memory of Professor Chandrasekhara Venkata Raman's life and work, his courage, his faith in young men and women and his ceaseless quest for truth be an inspiration to the young people of our country.

Raman's thoughts

"WHAT is Research? It is only seeking after knowledge and must therefore be of the utmost fundamental significance in all schemes of education. You must remember that knowledge at the present day is not a dead knowledge enshrined in books but a living and growing knowledge with which we are all concerned. Can you imagine for a moment that living knowledge can be procured, can be obtained merely by the study of books, by turning your teachers and students into mere book-worms? No! your teachers and students will have to take part in that stream of human activity, which I have referred to. A university is not a university if this is not understood, if this is not daily practised. It is in the attempt to discover new facts and new relations between known facts, which we call research, that a true insight into the new and growing body of knowledge is obtained. You must be one of the seekers, or else you will be left behind."

* * *

"I would warn my young friends very specially against regarding research as a pathway to self-advertisement and self-glorification. Self-advertisement for whatever reason it may be pursued, soon becomes an end in itself and its results are most evil when seemingly it is most successful. The man of science who habitually indulges in it soon comes to believe in his own perfection and infallibility and loses that clearness of vision and rigid self-criticism, essential to an investigator. Self-praise is scientific suicide".

* * *

"SCIENCE is nothing but a research for truth—truth not only in the physical world, but in the world of logic, psychology, behaviour and so on. The virtue of a truly scientific frame of mind is the readiness to reject what is false and untrue. It proclaims from the house-tops that there is no virtue in sticking to untruth. I think the latest biological discovery is that there is no fundamental cleavage between the life of man and the life of the lower creation and that salvation lies in the perfection of the biological instinct for the perpetuation of the race—the instinct to sacrifice the individual for the sake of the species". (Excerpted from *Indian Scientists—Biographical Sketches,* G.A. Natesan & Co., Publishers, Madras)

The Colours Of Roses

SIR C.V. RAMAN

THE popularity of the rose has led to great efforts being made towards the development of varieties exhibiting diverse habits of growth and flowering and especially those producing large blooms with numerous petals and attractive colours. Hundreds of named varieties have thus been created and widely distributed. They are to be found listed and illustrated in several publications. The colours which are forthcoming are so striking and so varied that considerable interest attaches to the problem of their origin.

The first step towards the elucidation of these colours is to classify them into distinct groups. We may begin with some familiar groups. We may begin with some familiar colours, viz., yellow, orange, scarlet, red and crimson—limiting ourselves to those cases in which these colours exhibit the maximum degree of saturation or fullness. But not all roses can thus be described. Many present similarity in colour to spectral yellow, orange or red, but are of less saturated hues. Other colours, again, bear no resemblance to any of the pure spectral colours. Various special names have been given to rose colours, viz., cream, pink, salmon, vermilion, mauve and lilac. To this list must be added the multicoloured roses which display different colours on the front and reverse faces of the petals, e.g., scarlet and yellow, or red and white, while others present areas different in colour on the same side of the petals.

The genesis of the colours

We are chiefly interested here in the chemical problem, in other words, with ascertaining the nature of the pigments present in the petals which absorb the light rays incident on them, the rays which escape such absorption and emerge as diffused light determining the observed colours. Observation of the flowers held in sunlight through a pocket spectroscope reveals that roses exhibiting vivid colours such as scarlet, red or crimson completely absorb most of the visible spectrum, allowing only limited regions of it to escape as diffused light. Similar observations with the less vividly coloured roses indicate only the parts of the spectrum which suffer the greatest measure of absorption. Thus, in either case, the information which is forthcoming does not enable any definite conclusions to be arrived at regarding the absorptive properties of the pigment over the entire range of the visible spectrum.

In these circumstances, it becomes necessary to rely on the study *in vitro* of the pigments extracted from the rose petals by solvents which do not fundamentally alter their optical behaviour. The two solvents which have been employed in the author's studies are ethyl alcohol and acetone respectively. Rose petals immersed in ethyl alcohol are bleached and given sufficient time become practically colourless. With yellow roses, or with multicoloured roses exhibiting yellow faces or sectors, the alcoholic solution exhibits a golden yellow colour. On the other hand, the alcoholic extract of other roses is quite colourless, from which we infer that the pigment responsible for the colour of such roses has gone into solution, but has simultaneously been transformed into a colourless product.

Rose petals immersed in acetone behave differently. Yellow roses, and the yellow areas in multi-coloured roses are not immediately affected. But roses of all other colours and the areas on multi-coloured roses exhibiting colours other than yellow are quickly decolourised, and as the pigment is extracted from the petals, it dissolves in the acetone which then acquires its colour. The acetone extract may then be transferred into an observation tube with flat ends. Viewed against a bright source of white light through a pocket spectroscope, the absorption spectrum of the solution is seen by the observer. The concentration of the acetone extract can be varied by using fewer or more petals as the case may be and adjusting the quantity of acetone used for the extraction. It is also useful to have observation tubes of greater or shorter length, as may be found desirable, depending on the strength of the coloured extract.

Observations made in this manner with the acetone extracts reveal that the extracted material is much of the same nature in all the cases which have been studied by the author. Crimson roses, red roses, scarlet roses, orange roses and roses which are a light pink or a deep pink, all present spectra which are very similar in appearance. The long wavelength region in the spectrum extending from 600 mμ upto the red end comes through in full strength. But the yellow and green sectors of the spectrum between 600mμ and 500mμ are strongly absorbed. Darker bands in which such absorption is a maximum are clearly visible respectively in the green and yellow parts of the spectrum. There is also an observable transmission of light in the blue region of the spectrum.

The alcoholic extract from yellow roses examined spectroscopically exhibits an absorption which covers the short-wave end of the spectrum and extends a little beyond the blue upto about 515 mμ.

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Spectrophotometric study

Fig. 1 is the spectrophotometric record obtained with the acetone extract from a rose of a deep red colour held in a cell of one centimetre thickness. The figures entered are wavelengths in angstroms. The extract had to be diluted with acetone to enable the nature of the absorption to be clearly recorded. It will be seen that the record exhibits three distinct humps appearing respectively in the yellow, in the green and in the blue-green regions of the spectrum. These features exhibited by the record indicate that the pigment responsible for the colour of the red roses may be identified with the material designated by the author as Florachrome B.

Fig. 2 is the spectrophotometric record of the alcoholic extract from a yellow rose. The figures entered are wavelengths in angstroms. The absorption is manifested only in the blue region of the spectrum and the three peaks which appear in the record are an indication that the pigment which gives the characteristic golden-yellow colour to the extract belongs to the well-known class of organic compounds known as the carotenoids.

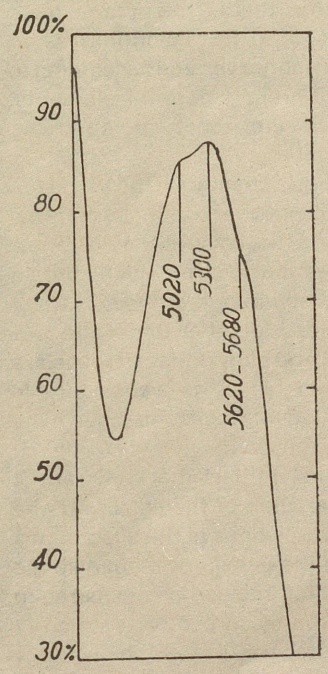


Fig. 1. Absorption spectrum of red rose

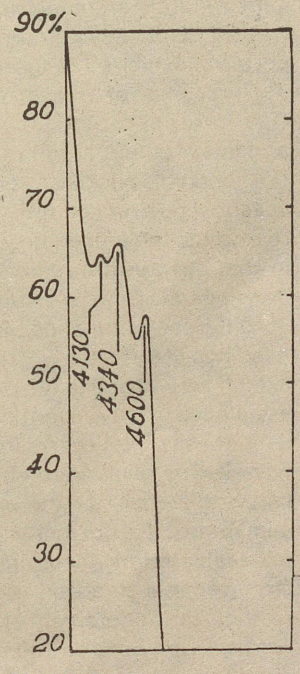


Fig. 2. Of yellow rose

Explanation of the colour variations

The features noticed in the recorded curve of absorption appearing as Fig. 1 enable us to give a reasonable explanation of the great range of colours actually exhibited by roses. The factor which is different for the roses of different colour is the quantity of pigmentary material present in the petals. On the basis of such variation, it is possible to deduce the results to be expected and compare them with the actual facts of observation.

We may begin with the cases in which the pigment is present in minimal quantities. It is evident from Fig. 1 that in such cases, the absorption of light by the petals would be principally observed in the range of wavelength from 500 mμ to 550mμ and that it would be much less both at greater and smaller wavelengths, becoming altogether insensible as we approach the red end of the spectrum. Examination of pink roses held in bright light through a pocket spectroscope discloses just such a situation. Further, it is found that the deeper the pink colour of the rose, the greater is the absorption noticeable in the green sector of the spectrum between 500 mμ and 550 mμ. But both the red and the blue regions of the spectrum persist.

We may next consider the cases in which the pigment is present in substantial quantities, sufficient to make the absorption by the petals completely effective except in the regions of the spectrum where the absorptive power is quite small. Referring again to Fig. 1, it will be seen that in such cases the light which escapes such absorption could appear only at the extreme red end of the spectrum, and the rose would appear of a deep crimson colour. With less pigment available, wavelengths upto about 600 mμ could escape complete absorption and the colour of the rose would then be a bright red instead of a deep crimson. When the quantity of pigment available is still smaller, wavelengths between 570 mμ and 600 mμ would commence to appear in the light diffused by the petals and the colour of the rose would alter from red to scarlet. With further diminution of the quantity of pigment available, the light diffused by the petals would extend further towards still shorter wavelengths and the colour of the rose would alter from scarlet to orange. Actually, when orange roses are viewed through a pocket spectroscope, we find that the spectrum from the extreme red upto 550 mμ comes through. while shorter wavelengths are absorbed. In all these cases, the blue region of the spectrum is scarcely to be seen.

The author has not had an opportunity of examining roses which have been described as exhibiting purplish hues. If blue roses were ever forthcoming, they would assuredly exhibit the spectrum of Florachrome A, with its characteristic bands of absorption in the red, yellow and green regions.

The spectrophotometer records reproduced above were made in the Instruments Laboratory of the Indian Institute of Science, to the authorities of which the author's thanks are due.

Ambition, Courage and Endeavour have been my watchwords —C.V. Raman

THE COLOURS OF GEMSTONES

SIR C.V. RAMAN

COLOUR is the sensation experienced by an observer when he views the material under study. It is, therefore, essentially a subjective phenomenon. While the optical properties of the material alter the spectral character of the light falling thereon and emerging therefrom which reaches the eye of the observer, the visual impression which such light produces is determined by the physiological characteristics of the sensory apparatus. These characteristics accordingly play the leading role in the perception of colour and must necessarily take precedence in all considerations regarding the subject.

The products of the plant world, including especially the leaves and flowers of living plants, constitute a very large class of materials exhibiting colour which invite study. Being products of biological activity, they conform to set patterns and are therefore exceptionally well suited for precise scientific investigations. The number of species of flowering plants is enormous, and the colours displayed by their flowers are of the most varied nature.

Another class of objects which exhibit colour and are worthy of study form the subject of the present communication, namely gemstones. In several respects, they are an antithesis to the products of the plant world when considered from the present point of view. For a material to be classed as a gemstone, it must be a rarity or at least so scarce as to be an expensive commodity, usually available only in small pieces and generally only after it has been converted by lapidaries into a form calculated to exhibit its lustre and beauty to the maximum extent and for that same reason wholly usuitable for any precise scientific investigation of its spectroscopic behaviour. It is the rarity and costliness of the gems which are natural products which motivated the efforts made to produce them synthetically, thereby creating for buyers and sellers alike, the acute problem of distinguishing between the natural and synthetic gemstones. Nevertheless, such questions, as for example, why is emerald green, why is ruby red and why is sapphire blue, possess both a human and a scientific interest. One can, of course, escape the difficulty of obtaining material suitable for the studies by employing the synthetic instead of the natural gems. But, then, the interest of the investigation and of its results would be materially diminished.

To the reader interested in gemstones and the practical problems arising in the identification of gemstones and of distinguishing between natural and the synthetic gems, Mr. B.W. Anderson's book on gem-testing (6th Edition, Heywood and Co., London) may be heartily recommended. The following remarks made by him which are pertinent to the subject may usefully be quoted here: "Minerals can be classified into the idiochromatic ('self-coloured') type which owes its colour to an element which is an essential part of its composition—*e.g.,* the iron in almandine garnet or peridot, the copper in malachite—and the allochromatic type, in which the colouring element is present in quite small quantity as an 'accidental' impurity. The majority of gem minerals are allochromatic: that is, the mineral itself has no distinctive colour, and is in fact colourless when pure, but exhibits a range of coloured varieties according to the presence of traces of different colouring elements. Quartz, beryl, corundum, tourmaline, topaz, spinel, zircon, and many others are in this category.

Anderson's book also contains a chapter on the use of the spectroscope in gem-testing which contains material relevant to the present topic, viz., the colours of gemstones. In that chapter are reproduced four charts which contain drawings made from visual observations of the spectra of 35 different gemstones, grouped together under the four headings of red, yellow, green and blue stones. The spectra exhibit very varied features, and this fact is of considerable assistance in the identification of the gemstones. The usefulness of the charts from this point of view should not however be allowed to obscure the fact that they cannot serve as a basis for the explanation of the colours of the gemstones. It is not merely the positions of the absorptions noticeable in the spectrum of the gemstones, but also the strength of such absorptions that has to be considered in relation to the intensity of the unabsorbed parts. In other words, we need a complete picture of the energy distribution or at least of the visual luminosities in the spectrum of the light emerging through the gemstone before we can proceed to consider the explanation of its visually observed colour.

It is naturally to be expected that the results which have emerged from the studies on floral colours would be found to be equally well applicable to the case of gemstones and enable us to give a satisfactory interpretation or explanation of their colours. The interest of the subject and the fact that a considerable collection of gem minerals was available in the museum of the Raman Research Institute induced the author to undertake some preliminary studies

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in this field with a view to find whether this is actually the case. The present communication is a brief report on the results.

We may first consider the case of emerald. The rich green colour characteristic of this gem is exhibited by numerous pieces of beryl purchased by the author some years ago at Jaipur in Rajputana and included in the collection of beryl specimens of various sorts deposited in his museum. Unfortunately, however, none of these specimens is transparent enough to permit of light transmitted in the regular fashion through it being observed or examined. However, the author was presented by Sri Chand Golecha, a leading jeweller of Jaipur, when he recently visited Bangalore, with a hexagonal crystal of beryl from the Colombian mines about one centimetre thick. The two faces of the plate facing each other were ground down and polished, and the material was then found to be fairly transparent and the transmitted light also exhibited the characteristic green colour of emerald. Visual spectroscopic examination, confirmed by photographically recorded spectra, showed that in the passage of light through the plate, the violet and blue sectors of the spectrum were noticeably weakened, especially the former. But there was a readily observable transmission in the wavelength range between 450 $m\mu$ and 500mμ. The green and the red sectors of the spectrum were also visibly diminished in their intensities in the light emerging through the plate. But such diminution was not more than could reasonably be ascribed to the loss by reflection at the two surfaces of the plate as well as the imperfect transparency of the material. On the basis of these facts, we should have expected the colour of the light emerging through the emerald to be a bright yellow, while actually it was a clear green.

We have now to consider the explanation of this striking discrepancy. There is indeed a weakening of intensity (including a narrow band of absorption) noticeable at and near the red end of the spectrum. But the visual luminosity of this part of the spectrum is so small that such absorption is incapable of explaining the fact that the observed colour of the gem is green and not yellow. A careful examination of the spectrum shows, however, that the part of the spectrum between 570mμ and 600mμ, in other words, the yellow sector of the spectrum is greatly weakened. It is clear that it is this extinction of the yellow that is responsible for the observed colour of emerald.

The results obtained with the hexagonal beryl crystal were confirmed with a fine piece of emerald of gem quality which was purchased from a jeweller at Bangalore. It is of much smaller thickness (about two millimetres) but exhibits a deep green colour. The yellow of the spectrum is found to be greatly weakened in the passage of the light through the gem. The aggregate intensity of the red sector relatively to the green sector is distinctly less than it is before entry into the gem, but it is far from being negligible. The observed vivid green hue of the emerald indicates that in the circumstances of the case, the visual sensation excited by the red sector is more or less completely masked by that of the more luminous green sector, in other words, prevented from influencing the perceived colour of the gem.

We shall next consider the case of the ruby. The author's collection of corundum from Ceylon includes numerous individual specimens exhibiting varied colours. Placing them under the ultra-violet lamp and picking out those which exhibit the characteristic red glow enables us to separate the rubies from other species of corundum. Such separation resulted in the interesting discovery that some rubies exhibit a purple colour. They show a strong absorption in the region of wavelengths between 560 mμ and 590 mμ, in other words, of the yellow sector in the spectrum. Their spectral behaviour thus closely resembles that of the purple flowers mentioned earlier.

Rubies which appear red owe their colour to the existence of an absorption covering both the yellow and green sector of the spectrum. It is a remarkable fact that the blue of the spectrum is transmitted more or less freely by such rubies. But it does not appear to influence the observed colour. We are led to infer that in the particular circumstances of the case, the weaker sensation due to the blue part of the spectrum is masked or prevented from being perceived by the more luminous red sector.

Flowers which appear of a blue colour invariably exhibit a strong absorption of the yellow of the spectrum. A very similar behaviour is found to be exhibited by blue sapphire.

We may sum up all that has been said above in a few words, viz., that the colours of gemstones exhibit features which are in complete accord with those met with in the realm of flowers.

The true role of scientists is the discovery of truth, they have no concern either with the application or misapplication of the results of scientific discoveries. All the same, scientists owed an obligation to society, to improve it —C.V. Raman

RAMAN— THE TEACHER EXTRAORDINARY

A. JAYARAMAN

I had the greatest good fortune to be closely associated with Professor C.V. Raman for eleven years (from Nov. 1949 to Oct. 1960), from the very beginnings of the Raman Research Institute, an Institution Raman created for pursuing his scientific interests, after retirement from the Indian Institute of Science. I began my scientific career with him as a research assistant and won his confidence and affection. He was extraordinarily kind to me and shared his scientific and other interests without any reserve.

Raman was a true scientist and lived all his life as an active researcher. In his scientific career he pursued his research interests with great vigour and set for himself highest-standards and goals. His immense curiosity for understanding natural phenomena, power of observation and persistence led him to make one of the greatest discoveries in physics namely "The Raman effect". It is of particular significance that the equipment which Raman employed for the discovery were very simple and amounted to a total cost of Rs. 500 at the time. Raman's discovery and his getting the Nobel prize was not only a personal triumph for him but was very significant for India and India's scientific development. For almost six decades Raman's personality made its deep impression on the Indian scientific scene. He inspired generations of students and was the most loved spokesman for Science. The story of his success has few parallels at least in the Indian context. His achievement can only be attributed to the singular nature of his personality, and the energy and vigour with which he pursued his goals. Raman showed an uncommon ability for independent thinking right from the beginning and gave up a lucrative government job in favour of a scientific career. When he took to scientific research he was supremely confident of outstanding achievement. Apparently he used to remark that he would bring the Nobel prize for physics east of Suez. Rabindranath Tagore had won a Nobel prize for literature in 1913, but Raman was the first Asian to win the Nobel prize in a scientific field. Viewed from the times in which he was born and raised, it was a statement no one lesser than Raman in determination could have made.

Raman was a towering scientific leader and trained a large number of scientists in India to assume leadership in the field. During his lifetime scores of students passed through his laboratory where they learned scientific methods of thinking, and methodology of scientific research. Raman was a source of tremendous inspiration for the young minds and he kindled their creativity and true interest in science. He gave them interesting problems, worked with them in understanding their results, and developed their analytical thinking and skills. He taught them how to write scientific papers and how to give an effective presentation to an audience. Raman's scientific papers were written in such a delectable style, they were like literary expositions. He often used Latin phrases to emphasize a point. His enthusiasm and curiosity about Nature were infectious. One imbibed a great deal of knowledge just observing him. Raman was indeed a teacher extraordinary the like of whom would be very hard to find.

The life and achievements of Raman are told in other articles in this issue and hence I will not dwell on these topics. My purpose will be to show what a great and gifted teacher Raman was and how he inspired his students and coworkers. He did not teach in the conventional way, although during his tenure as Palit Professor in Calcutta University he taught the M. Sc. classes to which I shall refer to later. One learned an incredible amount of physics by just being associated with him, listening to his lectures, in discussions with him and by observing him when he was working in the laboratory on a scientific problem. From him one learned how to appreciate Nature, for he had an intense curiosity about Nature and natural phenomena. Colours and symmetry in nature fascinated him and he tried to understand them deeply from the point of view of a physicist. It was the colour of the sky and the blue of the ocean that set him on the trail of discovery of the light scattering effect named after him.

Dr. Jayaraman was a close associate of Professor C.V. Raman with whom he worked from 1949 to 1960, at the Raman Research Institute in Bangalore. He is currently a Distinguished Scientist in the Physics Research Division of AT&T Bell Laboratories, 600 Mountain Avenue, Murray Hill, NJ 07974-2070, USA.

Raman the scientist

Raman went through four distinct phases in his life. Following a brilliant academic career he entered the Financial Civil Service in 1907, at the tender age of 18 ½, as an Assistant Accountant General in Calcutta. Driven by an irresistible urge to do scientific research Raman discovered the Indian Association for Cultivation of Science, soon after he arrived in Calcutta. From 1907 to 1917 he conducted experiments at the Laboratories of the Association during his leisure hours, which meant most mornings, evenings and weekends, and he published a stream of papers in the *Bulletins* of the Association and in foreign journals. His outstanding work on the acoustics of musical instruments and optics earned him name and international fame. Soon, students and disciples started gathering around him for participating in scientific research, and the Raman School of Physics came into being. This may be called the first phase and Raman's entry into physics seriously.

In 1917 Raman was offered the Palit Professorship at the Calcutta University by its distinguished Vice Chancellor Sir Asutosh Mukherjee. Raman gave up the lucrative government job and took up the Palit Professorship for a fraction of the salary that he was getting as an Officer of the Finance Department. Thus from 1917 Raman's career entered the second phase and he now became a full time researcher and a teacher at the Calcutta University. He took full control of the laboratories of the Indian Association for the Cultivation of Science as well as the laboratories at the Calcutta University. From 1917 to 1933 Raman held the Palit Professorship of the Calcutta University and it was during this period he took to light scattering studies which culminated in the discovery of the Raman effect.

Raman showed an uncommon ability for independent thinking right from the beginning and gave up a lucrative government job in favour of a scientific career

In 1933 he left Calcutta to become the Director and Professor of Physics at the Indian Institute of Science, Bangalore. He remained at the Institute of Science until his retirement in 1948. During this period Raman took a large number of students, trained them in research and launched them as physicists. He started the physics department and initiated research in several branches of physics; optics, spectroscopy, light-scattering, ultrasonics, x-ray diffraction. The period from 1933 to 1948 may be called the third phase in Raman's scientific life.

In 1949, after retirement from the Indian Institute of Science, Raman founded the Raman Research Institute for the purpose of pursuing his scientific interests, without the shackles of bureaucratic constraints. He took a few students in the beginning but that was only a trickle compared to the previous phases. He carried out research on the colours of gems and minerals, floral colours, diamonds, physiology of vision and a host of other topics in which he was interested. Whatever interested him became a topic of his study. He gave lectures on such diverse subjects as clouds, weather, atmosphere, vision, earthquakes, sound and hearing, apart from lectures on his scientific research studies. His customary Gandhi Memorial lecture every year in October became an event in Bangalore, when scientists and laymen heard Raman speak with great enthusiasm and fervour. Groups of college students and high school students visited the Raman Research Institute to have a darshan of the great scientist. His museum collection enthralled them. The Raman Research Institute itself with Raman as its central figure became a Mecca of science. A visit to this Institute and seeing Raman and talking to him became the most inspiring experience for anyone, particularly young students of science. Raman was an active scientist until the very end. Only for a month or so towards the end he had to be kept away from his beloved Institute. This may be called the fourth and final phase.

Raman was a staunch nationalist and was proud of his Indian heritage and its past achievements. He admired Mahatma Gandhi and Jawaharlal Nehru although he did not agree with all their policies. In the matter of scientific research he insisted that Indian scientists should not be camp followers and imitate what is being done in the west. He has proclaimed too often that what one does should not only be original but also be relevant to India's needs when it comes to application of research. He was opposed to Indian scientists going abroad for advanced research and believed that it impeded originality of thinking. It is difficult to say whether he was right or wrong but it is a fact that independent India is yet to produce scientists of Raman's caliber, although the money spent on scientific research is enormous compared to the Raman's days. Raman was a man of emotion and could get violently angry. But he had an incredible sense of humour and could keep an audience roaring with laughter just describing what could have been commonplace incidents. Anyone who met him could not but be struck by his zest for life. His exuberance was infectious. Chatting with him for some time was like taking tonic. To him scientific activity was the fulfillment of an inner need. His approach to science was one of passion, curiosity and simplicity. Science was to him a personal endeavor, and aesthetic pursuit, and above all joyous experience.

Raman as a classroom teacher

I quote from L.A. Ramdas' article on Raman as a classroom teacher "Prof. Raman, as a Palit Professor had no teaching responsibilities, but he enthusiastically took part in M.Sc. teaching. He held the view that when a leading research worker takes on some special teaching course, he brings to his teaching the freshness of research and the questioning attitude which makes all the difference between dull pedagogy and inspired teaching. To some of us who had joined the M.Sc. course at Calcutta (both myself and the late Dr. K.S. Krishnan had joined the M.Sc. course

in physics at Calcutta by 1920) Prof. Raman once made the side remark that the best way for him to master or revise any subject in physics was indeed to lecture on it to the M.Sc. classes.

"The M.Sc. teaching used to be naturally shared by the various Professors and Lecturers. Prof. Raman took 'Electricity and Magnetism' in the year 1920-21 and 'Physical Optics' in 1921-22. Both sets of M.Sc. students felt that they were indeed listening to a type of inspired teaching to which was brought all the original flavour and excitement of the great giants of the past who had built up the subject under treatment. In listening spell-bound to Prof. Raman's lectures in 'Electricity and Magnetism', covering a series of nearly 30 lectures, we had shared with him much of the excitement and superb thrill that Benjamin Franklin, Oersted, Arago, Gauss, Faraday, Maxwell, Hertz, Lord Kelvin and many others must have felt while they were making their actual discoveries. This was indeed no routine text-book learning, but reliving the actual past history of the subject. Almost regularly, Prof. Raman with his genius for the subject, his extraordinary eloquence, imagery and fullness of precise expression used to forget himself as well as the time and used to lecture for far more than the prescribed one hour, while the next lecturer had to politely (and perhaps with a sense of relief) retire from the scene after seeing Prof. Raman still at his lecture! Often he used to take the entire forenoon, more than 2 and sometimes even 3 hours—such was his tremendous love of teaching. The mathematics was worked through often with his own improvised simplifications and fully illustrated with physical analogies. Any question or point raised by a student would start off towards uncharted grounds, not touched upon in any text-book. His ready wit and sparkling intellect were a treat to the classes. And after each lecture we used spontaneously to look up original papers and classical treatises like Maxwell's *Electricity and Magnetism,* J.J. Thomson's *Conduction of Electricity,* Faraday's *Experimental Researches,* Lord Rayleigh's and Kelvin's *Collected Papers* and so forth. The lecture in which he worked out Maxwell's field equations and showed that light waves are only electromagnetic waves and the thrill he communicated to the class are still fresh memories.

"In physical optics, a topic on which he himself was conducting several investigations at the time, the students were introduced to all the topics coming, as it were, hot from the 'Lab' and the lecturer's flair for dipping straight into the works of great masters like Huygens, Fresnel, Mascart, Schuster, Wood, Rayleigh, and others of the late 19th and the early twentieth centuries imbued the students with a real love and enthusiasm for what they learned at Prof. Raman's feet, as it were. Whether the subject was Thermodynamics, or the Kinetic theory of gases, or Modern physics, Prof. Raman's treatment of the topic at hand was original and inspiring and left a permanent impression in the student's mind.

"Now let me record a few reminiscences. As an M.Sc. student having direct and free access to Prof. Raman's own personal library, I was astounded to discover that in each and every text book from which he had learned in his own student days, there were marginal criticisms or appreciations of the author. There was no book in which every example and question had not been worked out by Raman. Some questions had the side remark "excellent", while not a few were apostrophized as "elementary" or "silly"! I had no doubt that Prof. Raman had been a most painstaking student and that the definition of 'genius' as the 'capacity to take infinite pains' is indeed true."

Professor Raman thus fully participated in teaching and inspired his students with his enthusiastic lectures. M.N. Saha who later became famous for the "Ionization equation" named after him and S.N. Bose, discoverer of "Bose statistics" were some of the other lecturers at the university college in 1917.

He was opposed to Indian scientists going abroad for advanced research and believed that it impeded originality of thinking

Professor extraordinary

The period between 1920 to 1928 may be said to be the golden period in the scientific life of Raman. With the combined control of the Association and the University Laboratories he had a hectic schedule. L. A. Ramdas has summarized this activity as follows:

"The daily activities at the laboratories of the 'Association' usually started by 7 a.m. Having started an experiment, one would go on working until 1 p.m. After a quick lunch the scholars would be back by 2 p.m. and work on far into the evening and often until 9 or 10 p.m., until the job on hand had reached a satisfactory stage. Working at this furious rate it is no wonder that many of the pupils could work through 5 or 6 major investigations each year. Those who could not cope with such a fast tempo of work would automatically drop off.

"By 1920, Prof. Raman had gathered round himself an increasing number of extremely bright and capable pupils so that, more and more, he could get his research programme executed rapidly by them. He inspired his scholars to use their own initiative and ingenuity to the fullest extent. He would see what was going on and discuss results at intervals. At any given time, however, he would concentrate his attention on the particular scholar who was then entering the most critical phase of his research. Interpretation of results, fruitful suggestions to carry the investigation several stages further and quick discussion of results already obtained resulted in an immediate publication from this effective type of collaboration between the Professor and the pupil. Each of his pupils had his opportunity for such exhilarating collaboration at the developing phase of his investigation. All the time, the

pupils enjoyed the fullest freedom to think, work and improvise for themselves. Spoon-feeding of any kind was absolutely taboo. A spirit of perfect understanding and goodwill pervaded the entire 'Association', with Ashu Babu, the Assistant Secretary, ever ready to help us with any material or facility that we needed, the scholars themselves helping each other spontaneously."

Raman very much maintained the above mode of working and dealing with students throughout his career. Anyone who wished to work under Professor Raman as a regular student had to undergo a searching oral examination in which the candidate's knowledge of fundamentals and capacity for original thinking would be severely tested. Although Raman attached importance to academic records, he always made his own assessment. Once selected, the students felt at ease and he was kind and large-hearted. He had his own way of developing self-confidence and self-reliance in them. He would treat them as his equals, while discussing scientific matters. It was his habit to go round the laboratory every morning, meeting each student, discussing the progress of his work and often suggesting new ideas. He would give free expression to his joy when a new result was brought to his notice. Nagendra Nath, an illustrious pupil of Raman says "One day when I told him that I had found the explanation of the Raman line in diamond which had been mentioned by him as an outstanding problem in his Nobel address, he asked me what it was. I said that the Raman line was to be attributed to the mutual vibration of the two face-centered lattices composing the diamond lattice; he simply yelled out, "You are right, you are right," and insisted that the research paper should be immediately written up. He was in ecstasy over this work. I found myself elected to the Fellowship of the Indian Academy of Sciences, at the age of 23, of which Professor had given no inkling to me."

Raman's students came from all over India. He chose them on the basis of merit and shaped them into scientists who went out to carry on the tradition of research wherever they went and worked in their subsequent career. Throughout his life he had a very warm corner in his heart for his many pupils and they knew they could always look up to him for any help that they may need.

In his public lectures, he would refer to his students by name and talk about their work. All this was thrilling experience to young students and powerful incentive for hard work. A unique rapport was established between him and his students.

Raman as a lecturer

Raman excelled in public speaking and could give a lecture, for instance, on Egyptian History off his cuff. His scientific lectures were a treat and he was a superb entertainer. His lectures were replete with spontaneous jokes and were delivered in his high-pitched resonant voice which reached the entire audience (no loud-speakers necessary). Rich in imagery and eloquence, the lectures were rendered in so popular a style that every listener felt that he understood all the science that the learned lecturer was discussing. Once he told me that "the hallmark of a good speaker is that the audience must be under the delusion that they have understood everything that was said by the speaker." In the minds of thousands of his listeners, whenever he gave a public lecture, he used to create the illusion that they understood everything of what he spoke about.

Raman's typical way of giving a lecture is beautifully summarized by Kashyap. "A tall, turbaned figure, casting those searching and curious eyes almost with child-like fitfulness, would walk directly to the dais, with an occasional turn to the right or left, acknowledging a remark or answering a query by the sponsors of the lecture who were leading him to the dais. Confidence incarnate was the figure and even before he started speaking, one got the impression that here was a lecturer who would deliver the goods.

Anyone who wished to work under Professor Raman as a regular student had to undergo a searching oral examination... Although he attached importance to academic records, he always made his own assessment.

"His very presence perhaps cut short the longwinded preambles and welcomes that often mar the beautiful effect of a nice lecture. Prof. Raman meant business and a disapproving look would stop a vagrant introduction. His first words uttered in a characteristically punching manner would set the pace for the lecture.

"He spoke of soap bubbles. And, mind you, for some half an hour the evanescent soap bubble that hardly lasts for a couple of seconds blissfully lived!

Raman asked 'Have you ever thought of keeping the soap bubble alive for a long time?' An intriguing question — a question that had never occurred to many. The problem you know, Raman went on to say, is to see that the droplet of water does not collect at the bottom. Then he went on to say how he and other scientists, some in France, managed to keep a soap bubble alive for a few days by subjecting the bubble to an oppositely directed force.

"One would never have a dull moment and would not even realize that the lecture is over. To listen to Raman was something more than learning physics. He had the knack of using the most appropriate expressions, which no textbooks could give. He had the habit of tugging the lapels of his coat which was a Raman characteristic. He would invite questions and answer them all with astounding clarity."

He was forthright when he criticized. During the annual meeting of the Indian Academy of Science in Baroda in 1958, he interrupted the talk of a high-energy physicist who was filling the blackboard with mathematical equations and

said "my dear fellow please try to explain what you have done in a few sentences. If you cannot do this, it is not worth knowing."

Concluding remarks

No single person has done so much for Indian science as Raman. Through personal example of his highest dedication to science, through his success as a teacher-cum-leader in training generations of physicists who in turn have created independent schools of research, through creating scientific Institutions and facilities for research and founding scientific Academies and Journals for dissemination and propagation of science and through his gift of eloquence which served to inspire and stimulate a widespread interest in science, Raman as a single individual has tremendously influenced the progress of science in India.

He was one of the rare breed of men who are no more, who ranged freely in all fields of science from physics to chemistry to biology. Raman stands alone as the greatest scientist that India gave to the world. Just as our poet Valmiki in describing the battle between Rama and Ravana has said in the great epic *Ramayana* "The sky is comparable only to the sky, the ocean only to the ocean and the battle between Rama and Ravana only to the Rama-Ravana yuddham (battle)," in modern India, Raman is comparable only to Raman.

C.V. Raman—Honours and Awards

1. Gold Medal for standing first in M.A. Exam. of Presidency College, Madras—1901
2. Elected Fellow of the Royal Society of London—1924
3. Mateuchi Medal (Rome)—1928
4. Knighted by the British Government—1929
5. Hughes Medal of the Royal Society—1929
6. Nobel Prize in Physics—1929
7. Appointed First Indian Director of the Indian Institute of Science—1933
8. Appointed First National Research Professor of Physics—1949
9. Franklin Medal of the Philadelphia Institute—1951
10. Bharat Ratna—1954
11. International Lenin Prize—1957
12. Appointed Member of the Pontifical Academy of Sciences by Pope John XXIII—1961

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Raman's Humour

Raman was rarely seen minus his familiar turban. He was once questioned as to the regularity of its presence on his head. "Why, to prevent the head from swelling", he promptly quipped.

* * *

Raman was equally famous for his ego. In early 1907 after passing the M.A. examination with flying colours, he appeared for the Final Civil Service, which is the forerunner of today's IAS. After returning from the interview Raman said to his brother, "I took one look at the faces of all the fellows who had come for the interview, and I knew I was going to stand first!" Raman duly stood first in the FCS examination.

* * *

On one occasion when he was provoked by a newspaper reporter, he said pointing towards the Raman Research Institute set up by him, "This Institute is a monument to my egotism. I am an egotist and just as the Egyptian Kings used to build pyramids before their death, so is this Institute my pyramid".

* * *

He was one of those courageous men who did not hestitate to call 'a spade, a spade'. If he felt that the approach to a problem was wrong, he bluntly said so. In a function organised on the occassion of his 80th birthday speaker after speaker extolled his science. When it came to Raman's turn to reply to the felicitations, he remarked, "I wish someone had said that I had the heart of a lion".

* * *

Once while returning to India from abroad Raman was deeply attracted by the intense blue of the Mediterranean Sea. It was there he began his studies on the scattering of light by liquids. In fact, Raman started his investigations right on the ship using polarizers, a small prism and a pocket spectroscope which he always carried with him. And he wrote two papers for *Nature* on board the ship S.S. Narkuda, one of which he mailed from Aden and the other from Bombay harbour. Perhaps the first instance of papers being written on a ship.

* * *

Raman once introduced one Dr Rahm to Mahatma Gandhi. Dr Rahm was a Swis Scientist who was studying the tiny organisms known as Tardigrada which survived even when held at very low temperatures. Dr Rahm after paying his respects to Gandhiji asked him if there was no way of ending the conflicts so rampant in the world. "If we cannot unite, can't we fight atheism which seems to be so much on the increase?" he asked.

Sir C.V. Raman put in : "I shall answer your question. If there is a God we must look for him in the universe. If he is not there, He is not worth looking for. I am being looked upon in various quarters as an atheist but I am not. The growing discoveries in the science of astronomy and physics seem to me to be further revelations of God. Mahatmaji, religions cannot unite. Science offers the best opportunity for a complete fellowship. All men of Science are brothers".

"What about the converse? All who are not men of science are not brothers?" Gandhiji asked.

The distinguished physicist saw the joke and said "But all can become men of Science".

* * *

On an occasion when introduced to a gathering as having been born in 1888, Sir C.V. Raman remarked wryly: "And now I have been introduced to you as a hang-over from the 19th century".

* * *

Raman was known for his brisk habits and almost irrepressible energy. Once as Deputy Accountant General he was transferred to Rangoon. One day an Accountant General who went round on a tour of inspection, was so much struck by Raman's aggressive individuality that he asked his superior. "How do you manage Raman?"

* * *

On another occassion Dr. King of the Benares Hindu University being struck by the marvellous energy of Raman's movements was forced to remark, "It is indeed a matter of surprise that flasks and test-tubes survive Mr. Raman's handling in the laboratory".

* * *

He was very fond of gardening and trees in particular. Once just before his last birthday he was taken ill. He spent a short while in St. Martha's nursing home, but wished to be taken back to his residence. Lying on the bed in his house he complained, "If I knew I was going to die here like this, I would have had the windows put in differently".

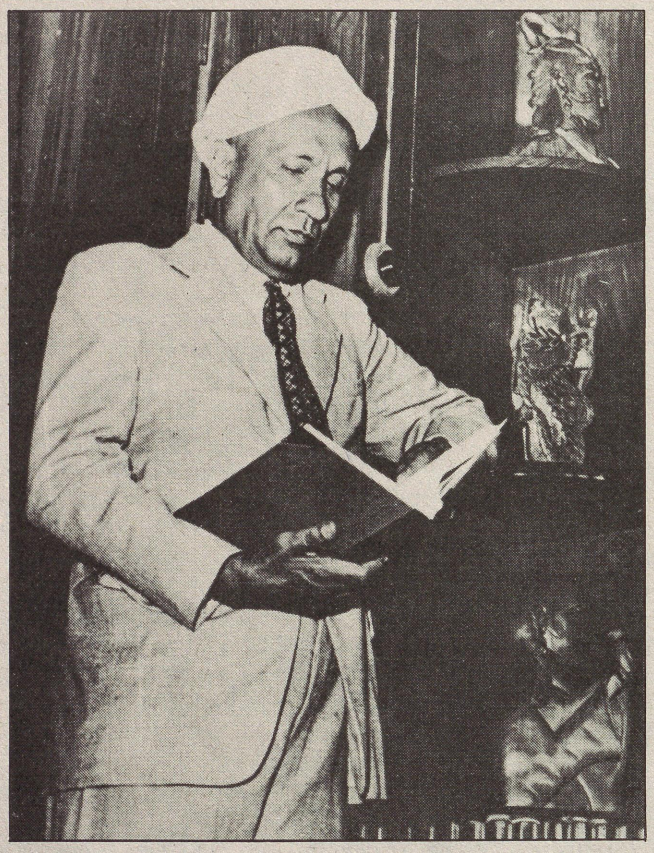
When asked what he meant, he said. "I can't see my trees!" And so the bed was raised so that he could feast his eyes.

* * *

Raman always took pride in the fact that his researches never involved costly equipment. Raman discovered the Raman Effect with the crudest of instruments, namely a mercury lamp, a flask of benzene and a direct vision pocket spectroscope! On one occassion, Raman is said to have remarked : "The essence of Science is independent thinking, hard work and not equipment. When I got my Nobel Prize I had spent hardly Rs 200/- on my equipment."

* * *

Excerpted from *Professor Chandrasekhara Venkata Raman* by S. Bhagavantam, Andhra Pradesh Akademi of Sciences, Hyderabad. and lecture delivered by Dr. G.Venkataraman, J.N. Fellow, Indira Gandhi Reactor Research Centre *by* Hasan Jawaid Khan



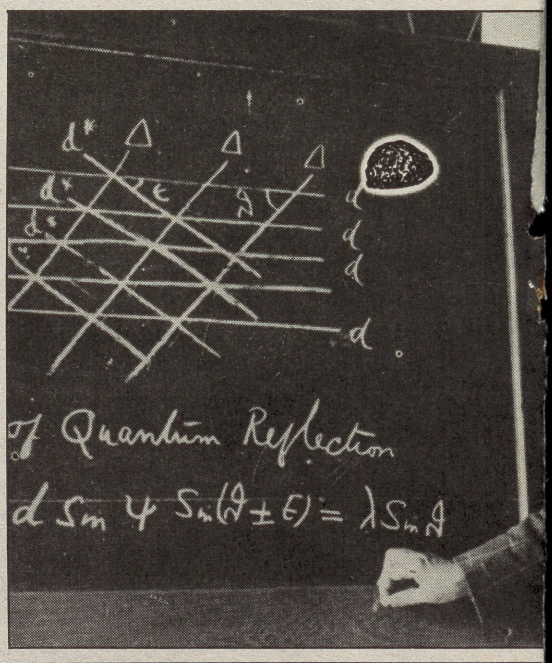
Engrossed in deep study



Explaining his experiment to Jawaharlal Nehru

A RAMA

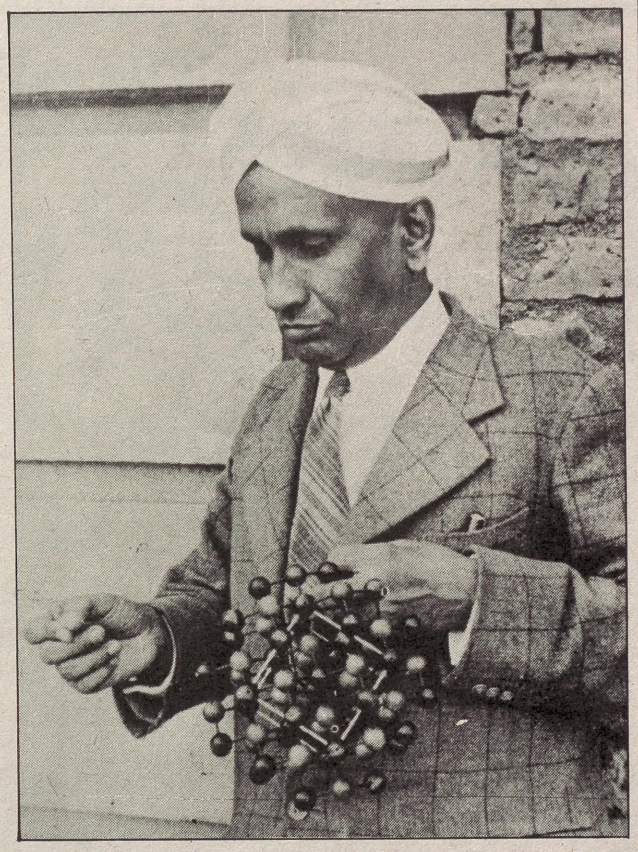




At the Indian Science Congress 1950 at Indian Institute of Science, Bangalore. Sitting left to right: C.V. Raman, M.S. Thacker, H.C. Dasappa (Minister, Mysore Govt.), Homi J. Bhabha (General President), Maharaja of Mysore. Prime Minister Nehru is seen addressing the gathering.



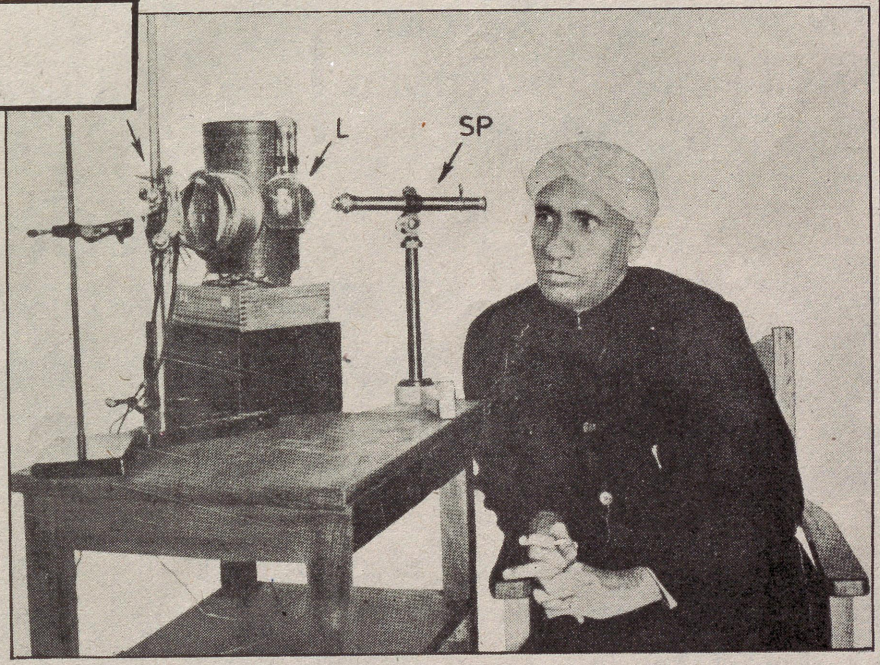
In his lab



Contemplating a model of a crystal

N ALBUM





Prof Raman observing Raman scattering phenomenon

Discussing the law of quantum reflection in his lecture room at the physics department of the Indian Institute of Science

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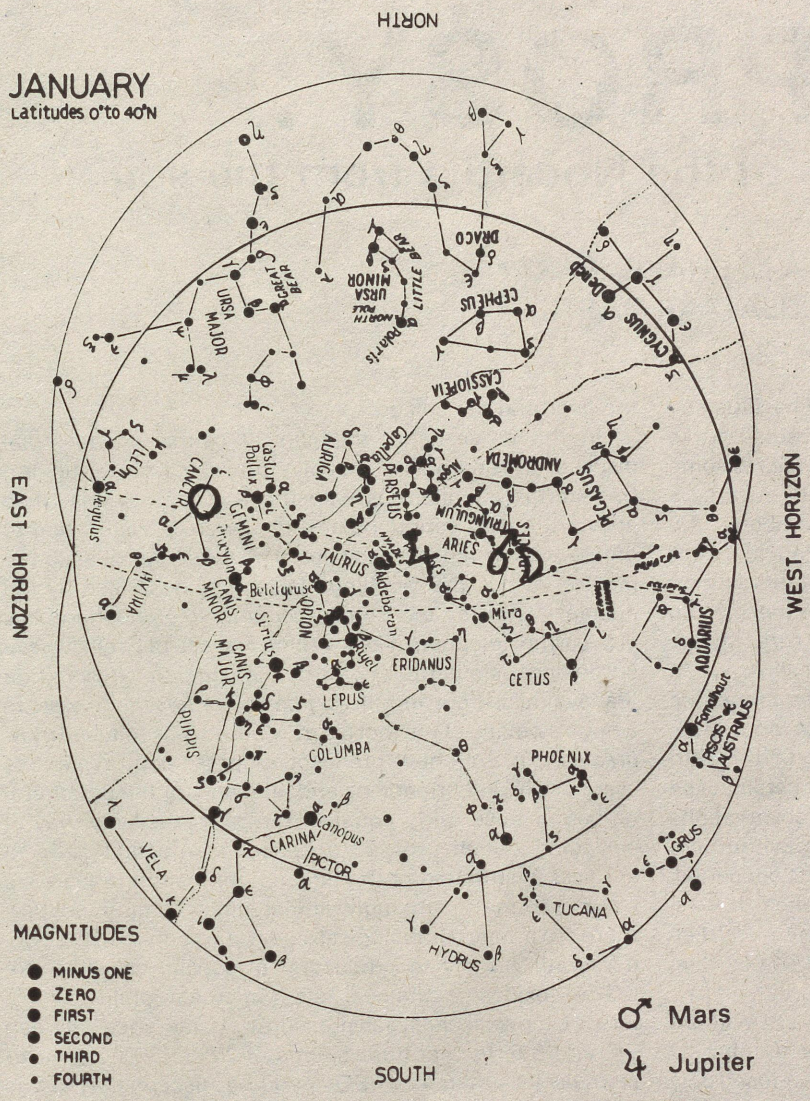
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Planetary positions for January 1989

Date	*1st*		*10th*		*20th*	
Planets	*R.A.*	*Decln.*	*R.A.*	*Decln.*	*R.A.*	Decln.
Mercury	19h 59m	22.6S	20h 46m	18.6S	20h 50m	15.5S
Venus	17h 07m	22.1S	17h 56m	23.0S	18h 50m	22.9S
Mars	1h 14m	8.4N	1h 31m	10.3N	1h 52m	12.4N
Jupiter	3h 39m	18.6N	3h 37m	18.5N	3h 36m	18.5N
Saturn	18h 24m	22.6S	18h 29m	22.6S	18h 34m	22.5S

Adopted from figures supplied by Positional Astronomy Centre, Calcutta.

The moon

THE new moon occurs on 8th at 0.52 a.m. and the full moon occurs on 22nd at 3.03 a.m. I.S.T. The moon passes about five and a half degrees south of Venus on 6th, about one and a half degrees south of Mercury on 9th, three and a half degrees north of Mars on 15th and about six degrees north of Jupiter on 17th. The moon is at perigee or nearest to the earth on 11th and at apogee or farthest from it on 27th. The lunar crescent becomes first visible after the new moon day in the evening of 9th.

The earth is in perihelion or nearest to the sun on 2nd.

The planets

Mercury (*Budha*), visible in the evening sky sets about an hour after sunset during the first three quarters of the month. Thereafter it comes too close to the sun to be visible being in inferior conjunction with the sun on 25th. It is in greatest eastern elongation of about 19° from the sun on 9th. It becomes retrograde on 16th. It is in Capricornus (*Makara*). Its visual magnitude varies from —0.7 to +1.6.

Venus (*Sukra*), visible in the morning sky rises one and a half hours before sunrise during the first half of the month and about an hour before it during the second half. It moves from Scorpius (*Makara*) through Sagittarius (*Dhanus*). It visual magnitude is about —3.9.

Mars (*Mangala*), visible in the evening sky sets at about local midnight during the month being in quadrature with the sun on 21st. It moves from Pisces (*Mina*) to Aries (*Mesa*). Its visual magnitude varies from 0.0 to +0.5.

Jupiter (*Brihaspati*), visible in the evening sky sets about two and a half hours after local midnight during the first half of the month and about one and a half hours after it during the second half. It becomes direct on 20th. It is in Taurus (*Vrisha*). Its visual magnitude is about —2.6.

Saturn (*Sani*), is too near the sun to be visible during the first half of the month. Thereafter, it becomes visible in the morning sky, rising about one and a half hours before sunrise during the month. It is in Sagittarius (*Dhanus*). Its visual magnitude is about +0.5.

(*Source:* Positional Astronomy Centre, India Meteorological Department, New Alipore, Calcutta-700053).

LEPROSY:

The Great Puzzle of the Nocardia from the soil

A.N. CHAKRABARTY
SUJATA G. DASTIDAR

WE have noted that although the leprosy bacillus still remains to be captured, it might have left some marks of its presence by paying fleeting and elusive visits to some culture media. Several bacteriologists have discovered a previously unknown type of growth (resembling the corynebacteria—mycobacteria—nocardia groups) after seeding media heavily with leprosy materials; on examination, these showed no signs of life, as these could not be revived on any known type of culture media. However, the 'foot-prints' left by this bacillus when examined under microscope showed them as branching filaments, clusters, globi, coccoid, spore-like and 'blue' bodies, and structures which stained even better with Gomori's stain for nocardiae than the acid-fast stain (used to identify mycobacteria) Figs. 1-4. These observations made the position of the leprosy bacillus within the *Mycobacterium* group quite doubtful. As doubts deepened, the chances of its being a nocardia brightened. It was, therefore, natural to compare and contrast the nocardiae with the leprosy bacillus, on as many points as possible, along with the diseases produced by them.

The Leprosy bacillus was found to infect, without manifestations of the disease, a very large number of people in the leprosy endemic areas; leprosy developed only in a few of those with impared immunity and that too after long intervals. *Nocardia brasiliensis* ran a similar course of infection and disease.

Leprosy manifests itself as swellings or nodules or a discoloured patch on the skin often with loss of sensation and characterised by inflammatory and proliferative changes in the connective tissue. It often begins at sites of injuries in the feet and hands, commonly seen in farmers, gradually spreading to other parts of the body. It responds best sulfa drugs (DDS). Mutilation, a form of 'spontaneous amputation' may be one of Nature's ways of riddance of the burden of the disease.

The leprosy bacillus can also affect several animal species. In mice, the changes are minimal, but the disease can affect peripheral nerves. In armadillos, the disease runs a severe lepromatous course with invasion of the internal organs, the central nervous system (not peripheral nerves), the liver and the spleen.

On the other hand, the clinical course of nocardial diseases in general, and that of *N. brasiliensis* in particular, has startling similarities with those of leprosy described above; the only variations observed were probably due to differences in the host species. The following reveals the picture vividly: the swellings in leprosy described by the ancient Greeks in their accounts of 'elephantiasis graecorum' (elephant-like swelling disease of Greeks) have surprising similarities with the Indian description 'Padavalmika' (foot anthill, in *Atharva-Veda)* which refers to a huge swelling of the feet (as in 'Madura foot') caused by *N. brasiliensis.* Both have predilection for the central nervous system (CNS) of armadillos and man and for the peripheral nerves of mice fairly equally. Ironically, the only way of salvaging patients of *N. brasiliensis* infection is by a surgical amputation of the limb (cf. mutilation in leprosy).

Apart from the strikingly similar clinical characteristics, there are numerous biological similarities between the two, e.g., with respect to production of special enzymes like DOPA—oxidase, catalase, etc.; microaerophilism (preference for weaker oxygen pressure); pH tolerance between 7.0 and 8.5; temperature optima of 27° to 30°C; an acid-fastness less than 4% H_2SO_4; pyridine susceptibility of this acid-fastness; antigenic sharing; and the production of the paradoxical and harmful 'immune-complex phenomenon' with an associated failure of the cell mediated immunity (Table 1). Like the leprosy bacillus, *N. brasiliensis* can exist as an intra-cellular parasite and change over to cell-wall deficient 'L' forms. A very curious but significant finding is the occurrence of a special but similar brown-coloured pigment protein in both—an iron-protein in leprosy-infected armadillo liver, and an identical one in the *in vitro* growth of *N. brasiliensis (Report,* 1983, 13, 14).

A strong argument used in favour of the leprosy bacillus being a *Mycobacterium* was the nature of its mycolic acid (a complex fatty acid) that envelops the bacterial cells. However, on the basis of the existing knowledge, the number of carbon atoms in the mycolic acid of nocardiae is around 60, while in that of the mycobacteria it is above 78. Since the number of carbon atoms in the leprosy bacillus is

Prof. Chakrabarty is Head, Deptt. of Medical Microbiology & Parasitology at Calcutta University. Prof. Dastidar is in the Department of Pharmacy, Jadavpur University, Calcutta-700032

between 60 and 76, it is more likely to belong to the nocardiae than the mycobacteria. Moreover, separation of this mycolic acid into fractions (by chromatographic means) showed a distinctiveness not shared by any mycobacteria, but which was closely similar to that of nocardiae.

Furthermore, it was believed earlier that electron microscopic studies were suggestive of a similarity of the leprosy bacillus with mycobacteria. Subsequent studies, however, proved this to be unreal. Likewise, for some time it was believed that there was a greater sharing of antigens (specific chemical groups which determine antibody response) between the leprosy bacillus and *Mycobacterium*

Table 1. Comparison of Leprosy bacillus (L) with the Nocardia (N) and Mycobacteria (M)

Sl. No.	Characters	N	L	M	Sl. No.	Characters	N	L	M
1	Extent of infection	+++	+++	++	42	m-mycolate: 2/3 spots	+(?)	+	—*
2	Very long incubation	+++	+++	—	43	m-mycolate: 4 spots	—	—	—*
3	Prevalence of disease	±	±	++	44	C No in Mycolic acid	⩽60	60-76	⩾78-98
4	Huge swelling/nodules	+	+	—	45	PGL—I	(?)	+	—
5	Injury to feet and arms	+	+	—	46	Immune-Complex	+	+	—
6	Incidence of mutilation/amputation	+	+	—		Phenomenon			
					47	Anaerobiosis	±	±	—
7	Virulence	±	±	++	48	Microaerophilism	+	+	—
8	Mouse footpad pathogenicity	+	+	—*	49	Growth at pH<6.5	—	—	+
9	Involvement of human skin	+++	+++	—*	50	Growth at 28°C	+	+	±
10	Vessels	++	++	—*	51	Growth at 37°C	—/+	—/+	+
11	Collagen tissue	+++	+++	—	52	Sensitivity to sulfa	+	+	—
12	Rhinitis	+++	+++	—*	53	D D S	+	+	—
13	Mouth	+	+	—*	54	I N H	±	±	++
					55	Streptomycin	—	—	+
14	Tongue	+	+	—	56	Lysozyme	—	—	+
15	Palate	+	+	—	57	Metabolism of paraffins	++	++(?)	±
16	Larynx	++	++	—*	58	Tetradecane	++	+	—*
17	Spleen	++	++	—*	59	Benzene	+	+	—
18	Liver	++	++	—*	60	Naphthalene	+	+	—
19	Bone Marrow	++	++	—*	61	Toluene	+	+	—
20	Eye	+++	+++	—*	62	Xylene	+	+	—
21	Cranial nerve V	+	+	—	63	Aniline	+	+	—
22	Cranial nerve VI	+	+	—	64	Diphenylamine	+	+	—
23	Ophthalmic nerve	+	+	—	65	Peptone, meat	+/—	—	+
24	Peripheral nerve	—	+	—		extract, egg			
25	CNS (Human)	+	—	—*		medium 199			
26	Peripheral nerve (mouse)	+	+	—	66	NH_3	+	+	+
27	Granuloma	—/++	+++	++	67	Gelatin	+	+	—
28	Coryneform arrangement	+	+	—	68	D N A	+	+	—
					69	Glucose	+/—	—	+
29	Branching Rt<	+	+	—	70	Glycerol	+/—	—	+
30	Acute<branching	—	—	+	71	Sucrose	—	—	+
31	Filamentous	+	+	—	72	Lactose	—	—	+
32	Dimorphism	+	+	—	73	Tyrosin	+/—	—	+
33	Non-solid/staining	+	+	—	74	Casein	+/—	—	+
34	Gomori's Stain	+	+	—	75	DOPA-Oxidase	+	+	—
35	Acid fastness at 20% H_2SO_4	—	—	+	76	Catalase	+	+	—/+
					77	Collagenase	+	+	—
36	Pyridine susceptibility	+	+	—*	78	Gelatinase	+	+	—
37	Arthrospore	+	+(?)	—	79	Ag sharing with N	++	++	±
38	Blastospore	+	+(?)	—	80	Ag sharing with M	+	+	++
39	Globi	+	+	—	81	G+C%⩽61%	+	+	—
40	Granules	+	+(?)	—	82	D N A Homology	(?)	+++	—
41	Blue bodies	+	+	—		with L			

+++, ++, + degree of positivity of a character; ± weakly positive; — absent; +/— or —/+ majority or minority members showing positive characters; —* occasional strains positive; (?) character undetermined so far.

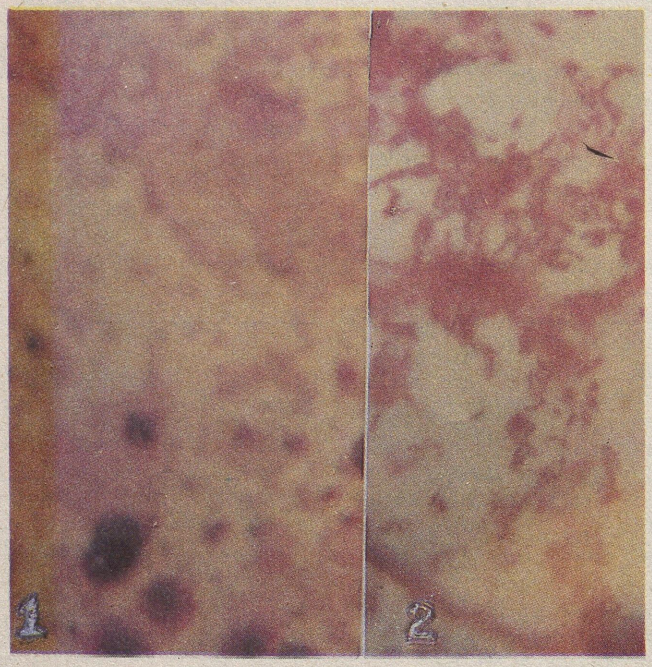


Fig. 1. (*left*) The leprosy bacilli staining red with acid-fast stain are seen in small clumps, clusters and globular masses ('globi') (800 x). (*right*) In early *in vitro* culture where the acid-fast bacteria had multiplied sufficiently, the bacilli are seen singly, in small groups and clumps. Some 'blue bodies' are noticeable on the left upper corner (800 x)

species compared with the Nocardia spp. However, several subsequent investigations have revealed a major sharing of antigens between the leprosy bacillus and the latter. Moreover, the unique antigen produced by the leprosy bacillus, called the phenolic glycolipid—I, (PGL—I) is not known to occur among mycobacteria at all; its presence among nocardiae had not been looked for as yet.

The numerous evidences considered so far (Table 1) certainly do not suggest that the leprosy bacillus could be a mycobacterium. Two other criteria, considered very weighty in assessing the inter-relationships of various groups, are the proportion of two bases (guanine and cytosine) in the bacterial DNA in the nucleus, and its DNA homology (closeness between the DNA of the two species). Both go very strongly against the concept that leprosy bacillus may be a member of *Mycobacterium*. It is interesting to note that the guanine + cytosine ratio of the DNA of the leprosy bacillus (57%-59%) is much closer to that of some nocardiae (61%-63%). Studies on DNA homology of the two may produce a conclusive evidence.

All these evidences show that only a few characters of the leprosy bacillus are shared (mostly singly) by random mycobacteria, while large groups of characters of the leprosy bacillus are common with most members of *Nocardia*. Although information on all the characters is still not complete, none of the many characters already considered disqualifies the leprosy bacillus from being a member of *Nocardia*; indeed, this itself is a strong point in its favour.

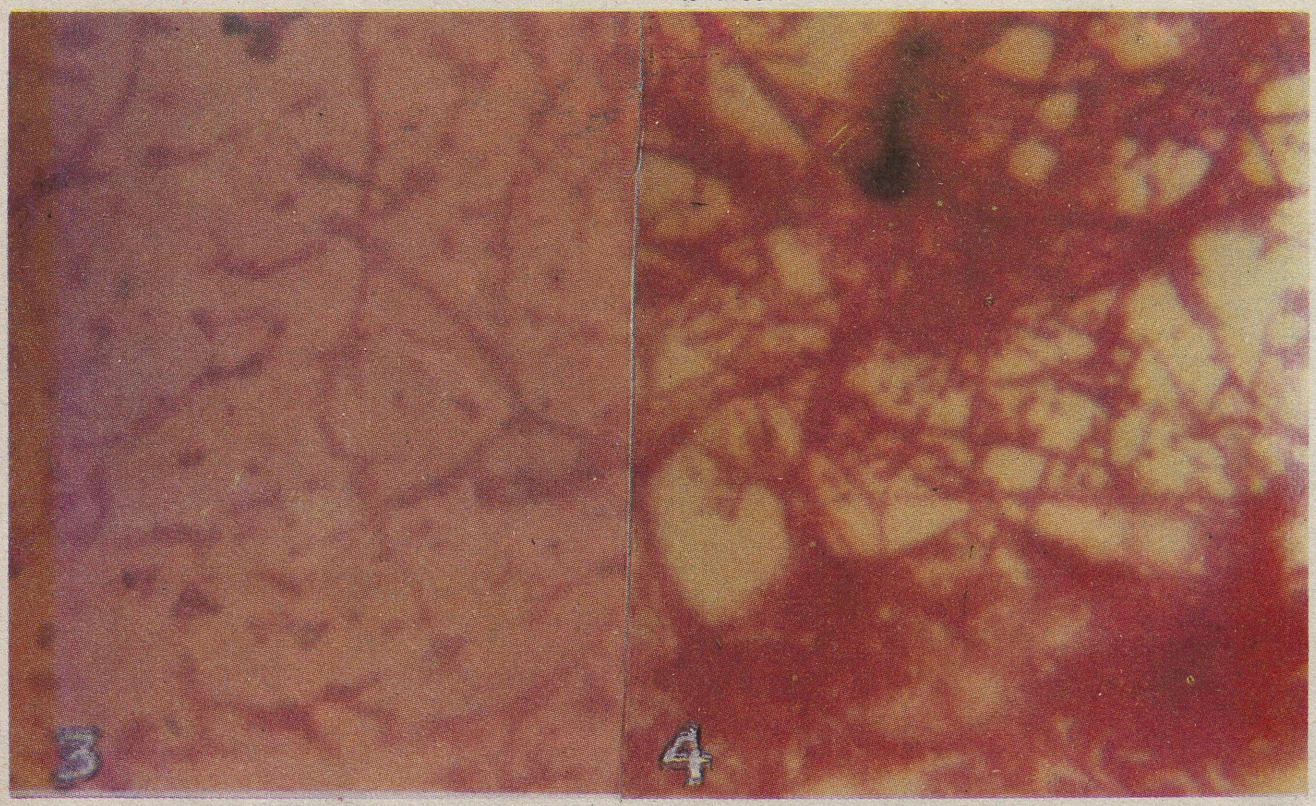


Fig. 2. (*left*) Early *in vitro* culture showing acid-fast brunching filaments, small-clumps and spore-like 'blue bodies'. Irregular and non-solid staining of these bacteria are seen at several places. (*right*) Advanced stage of growth and multiplication of acid-fast bacilli from leprosy in the test tube showing filaments fragmented into typical bacilli as well as into longer ones

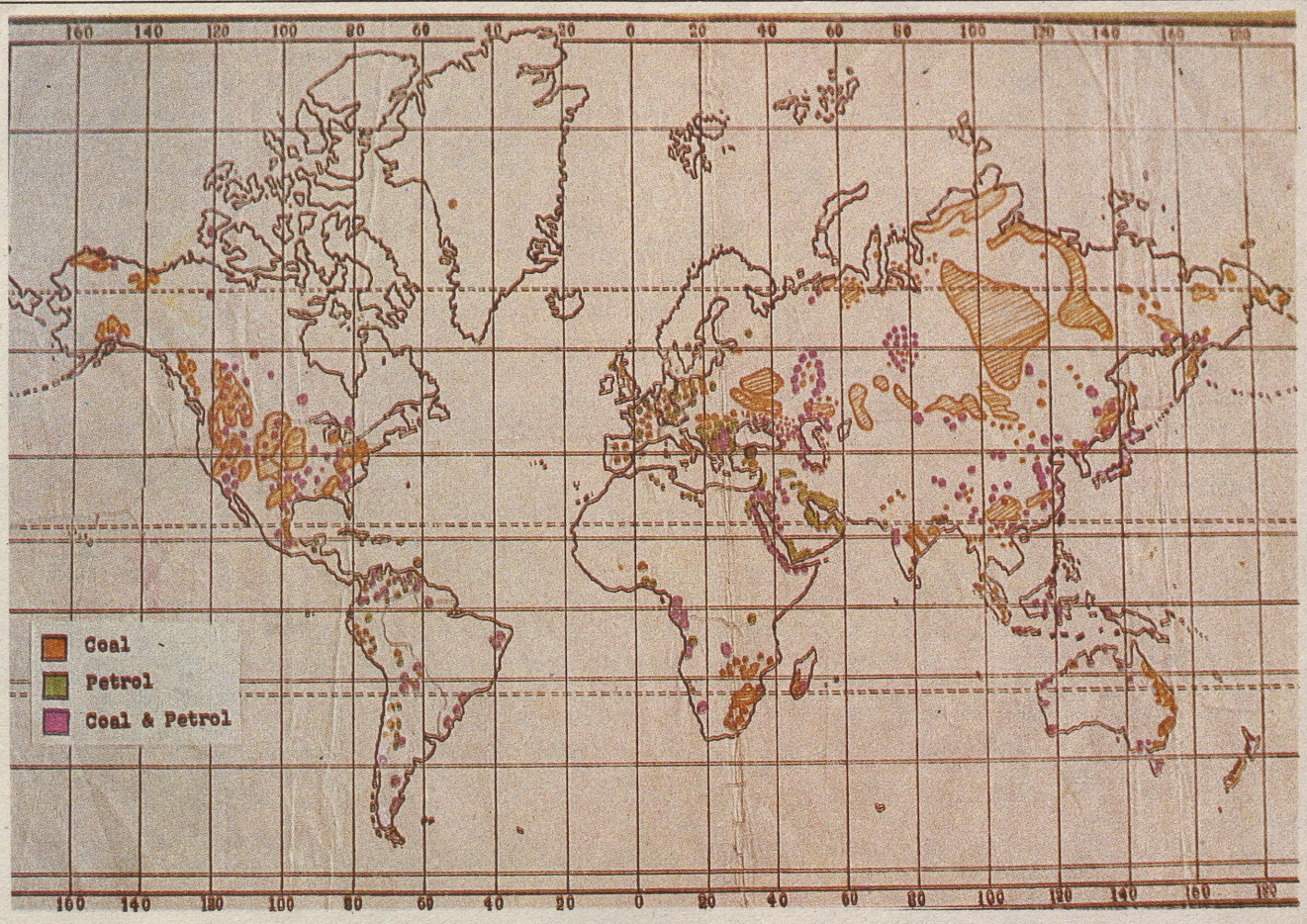


Fig 3. Fossil-fuel distribution map of the world

If, as pointed out earlier, the failure of attempts to cultivate the leprosy bacillus was indeed due to its mistaken identity, would it become possible to cultivate it on the artificial media used for nocardiae? It was found that the leprosy bacillus was still just as much non-cultivable on the media for mycobacteria as on those for nocardia as well as on every other known type of culture media for all types of microbes. This was a rude setback for all those who hoped to cultivate the leprosy bacillus on the lines of its nocardia-like characteristics.

However, there was a glimmer of hope. Chakrabarty, Dastidar and their colleagues realised that a majority of nocardiae preferred to grow on nutritionally simple media, e.g., liquid paraffins, ammonium sulphate, etc., although they could also manage to grow on rich media containing meat and yeast extracts, peptones, egg-proteins, serum or blood. A small minority remained, which was so choosy that it could only grow on media containing liquid paraffins, ammonium sulphate, etc., but not at all if beef and yeast extracts, egg proteins, blood and serum, peptones, etc., were served to them as food. This last group of nocardiae is known as 'chemoautotrophs' because of their capacity to use only the simplest chemical compounds of C and N, in a weak solution of mineral salts. The only remaining hope of cultivating the leprosy bacillus was therefore, its cultivation in a medium for chemoautotrophs (if it really were a chemoautotrophic nocardia) as this point had never been looked for earlier.

It was a real hit this time. The organism could be captured: It could repeatedly be cultivated from numerous leprosy patients, purified, preserved as well as kept going by continuous media to media transfers, using a few cells only each time. Their characters were the same as those of the leprosy bacillus (Table 1, Figs. 1-4). The most thrilling aspect was that all such bacteria (nocardia) from leprosy patients still refused to grow as stubbornly as did the leprosy bacillus itself (found by others and ourselves) on various conventional media. However, in captivity, they now lived merrily in their own chemoautotrophic medium and did **not** remain elusive any more.

Looking back, it appears that on several previous occasions also there had been attempts to cultivate the leprosy bacillus on some kind of simple (minimal) media, but without any significant or satisfying degree of success; possibly because highly rich supplements like yeast extracts, animal sera, amino-acids, hormones or enzymes, etc., were used in various combinations in all these cases. As we have already seen, far from helping the leprosy bacillus grow, these supplements actually harmed it by encouraging luxuriant growth of many types of companion or contaminant bacteria that were highly antagonistic towards the leprosy bacillus. These bacteria mostly

belonged to the corynebacteria-mycobacteria groups, that easily grew on the conventional media, and had repeatedly 'impersonated' the leprosy bacillus. The real leprosy bacterium, being a chemoautotroph, could not grow on any such rich media unless some traces of the leprosy tissue/juices persisted in the cultivation media. Investigations suggested that the 'juices' contained gelatin (normally not present in the tissues), produced by the breakdown of patients' tissue collagen by the collagenase enzyme present in leprosy bacillus. As we shall see below, gelatin is a readily utilisable substance for the growth and multiplication of the leprosy bacillus within the host.

Table 1 shows that, like most nocardiae, leprosy bacillus can also utilise gelatin, urea, asparagin, and several nucleic acid derivatives. Therefore, although it was found to be a chemoautotroph, it could attack some amides (e.g., urea) and gelatin, which could be considered as minor departures from its strict chemoautotrophy; this could also account for its pathogenicity.

The observations of Chakrabarty, Dastidar and their colleagues could be summarised as follows : (i) The acid-fast bacilli could be seen in plenty in all the cases of leprosy (Koch's postulate 1); (ii) These could now be successfully cultivated and maintained *in vitro* as nocardioform bacteria in all the cases studied (postulate 2); (iii) The bacilli obtained from leprosy tissues could be maintained *in vivo* by serial mouse to mouse passages in the foot pads (originally by Dr. Shepard and subsequently by Chakrabarty *et. al.*, on specimens obtained from his labs) and transmitted to the 9-banded armadillos for experimental production of a human type lepromatous leprosy (postulate 3). Infected tissues from several mouse footpads and armadillos when inoculated only on chemoautotrophic media produced nocardia like bacteria *in vitro,* very much like the bacteria recovered from humans, thereby strengthening the above postulates. All these different test-tube grown bacteria from human, armadillo and mouse specimens, moreover, when reinoculated in the mouse footpads, were found to have limited multiplications with minimal changes, just like the original leprosy bacillus (Koch's postulates reaffirmed). Taken together, these evidences established quite firmly the role of nocardial agents in causation of leprosy. Although several other tests still remain to be done to complete the picture bearing out the above conclusions, this role seems to be already very well founded in view of its unique history, elimination of the improbables and large number of confirmatory points, and leave little doubt as to the true nature of the agent discovered.

An interesting spin-off of the above work was the finding that these (leprosy) organisms, like other nocardiae, metabolise fossil fuels or their derivatives such as petroleum, jet-fuels, oil shales, asphalt, pitch, tar, bitumen,

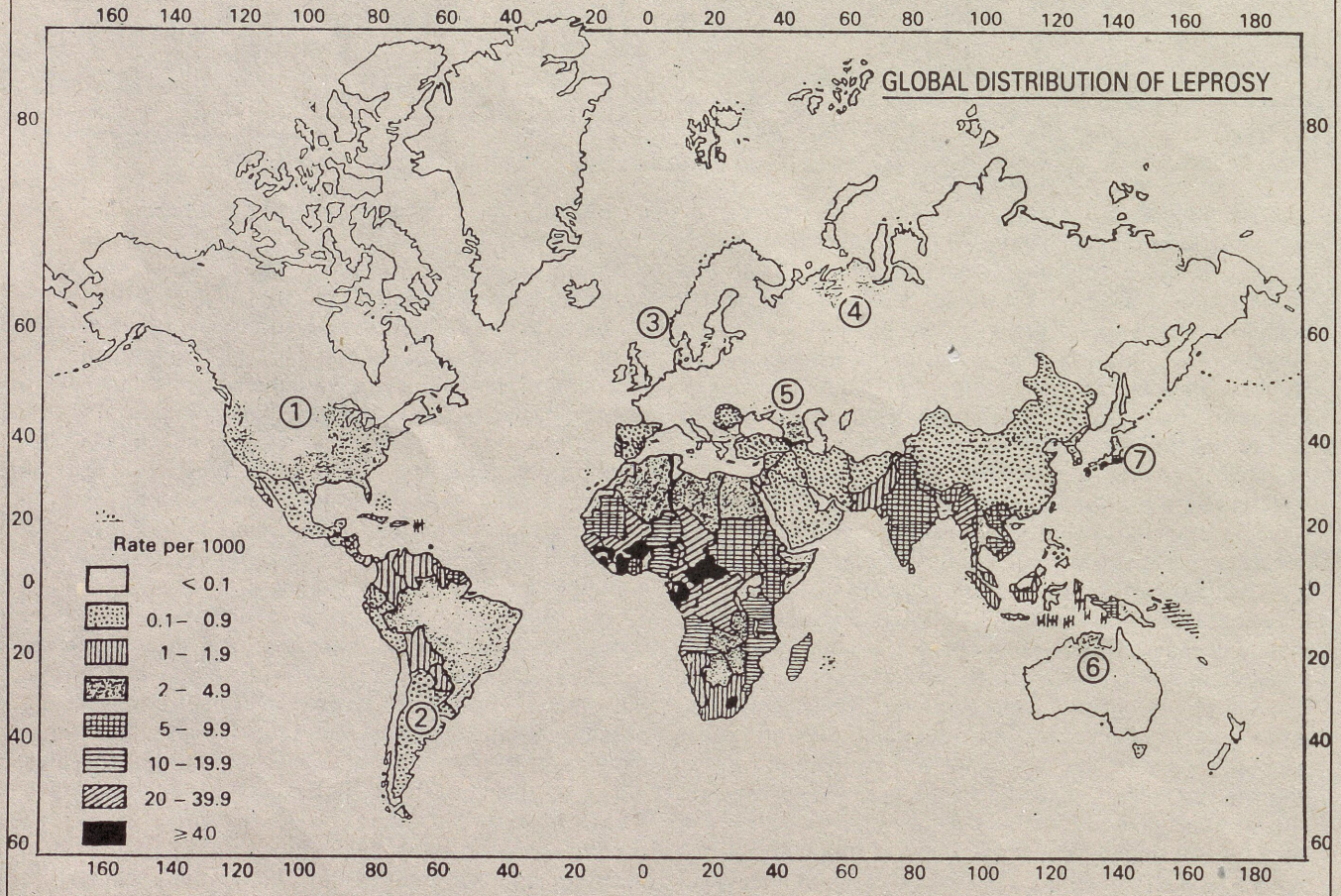


Fig. 4. Map showing global distribution of leprosy. Nos. 1, 3, 4, 5 and 6 denote areas where indigenous cases without contact originate; 2, remarkable endemicity in Argentina contrasting sharply with the neighbouring leprosy-free state of Chile

paraffins (cf. growth of leprosy bacilli in the wax of caterpillar wax moth, a bygone animal model) and such benzene derivatives as toluene, xylene, naphthalene, aniline, diphenylamine, etc., along with ammonium sulfate and trace elements. Theoretically it would follow that being fossil fuel metabolising bacteria, these would occur naturally in soils that have rich fossil fuel contents. This expectation has indeed been fulfilled as several groups of researchers have reported on the presence of leprosy-specific antigen (PGL-I) in the soils of leprosy endemic areas which implies the presence of the leprosy bacillus in the soil. In another study, a comparison was made between the global distribution of leprosy with that of fossil fuel derivatives in the soil and their manifold surface seepages in various metamorphosed forms. The results (Figs. 5 and 6) showed a remarkable correlation between the prevalance of leprosy and distribution of fossil fuels. This strongly suggested that leprosy among the tillers of the soil may primarily be due to a soil infection; the factors which make them particularly vulnerable are the nutritional or genetic immunodeficiency aggravated by community clustering (due to social ostracism) and encouraged consanguinity (marriage among close blood relations). The bacterium presumably enters the body through injuries on the feet and hands as well as by the respiratory route, just like other nocardiae. The indigenous (spontaneous, native) cases of leprosy without any human or animal contagion as occasionally found in the 'leprosy free' areas of the world (USA, USSR, etc.) strongly suggest such environmental infections. This would also explain occurrence of similar leprosy-like disease in armadillos, rats, cats, frogs, African chimpanzees and mangabee monkeys, buffaloes, etc. Large masses of epidemiological data support the idea of such an environmental infection, which is presumably carried from the soil, although till recently no direct confirmatory evidences seemed to exist.

Direct evidences (Chakrabarty, Dastidar and colleagues) came when it was found that soil from many fossil fuel-bearing countries of the world as well as coal and petroleum products yielded similar nocardia-like organisms. The capacity of these organisms to produce disease, however, remains undetermined, although actual detection of the specific marker of the leprosy bacillus (PGL-I) in the leprosy endemic and fossil fuel-rich soil meets this requirement considerably.

Does it mean then that leprosy does not spread from leprosy patients at all ? Even before the environmental (soil) infection theory could be conceived, it was becoming increasingly apparent that development of leprosy by man-to-man contagion had been much over-rated, and even among the good-for-life spouse, transmission was surprisingly low. There are numerous other anomalous evidences too, which greatly reduced the credibility of humans being the sole source of infection.

Despite soil infection emerging as a major, and possibly original source of leprosy infection, man-to-man infection does surely occur in parallel. This is evident from the virtual disappearance of leprosy after marked reduction in the scopes of human transmission of infection from almost whole of Europe, UK, USA, Canada, Australia and other countries, brought about by good living in hygienic condition, without over-crowding.

It is, therefore, not difficult to see that leprosy primarily results from soil infections (cf. *N. brasiliensis*). However, the human strains might have acquired a little greater virulence for establishing a man-to-man communicability by the respiratory route (cf. *N. brasiliensis* which cannot do so) among the immuno-deficient peasants who cluster among the consanguinity-prone hamlets; in this respect it is comparable with the *Yersinia pestis* (plague) infection in man which can 'take off' to the pneumonic form (man-to-man) from the bubonic (rat-to-man) one.

Leprosy, therefore, might have begun at the dawn of our civilisation when cultivation of land started and produced the first soil-to-man infection, in many fossil fuel-rich lands, *independently,* among the underprivileged, deprived and susceptible human beings, who were possibly the slaves.

This is how a brief narrative of the bacterium of leprosy and its communicability comes to an end. The horizon now looks much bigger with more lights, hopes, expectations and promises. It is so because the long elusive organism with extremely enigmatic characters had now been captured and may soon provide information much like other bacteria or microbes whose containment and eradication had become possible.

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Body's invisible soldiers

MAN lives in constant touch with microorganisms ever since his birth because the environment he lives in has myriads of microorganisms. The human fetus has no microorganisms until its birth. Under natural circumstances the fetus acquires microorganisms while passing down the birth canal either through contact, swallowing or inhaling. Within a few hours of birth micro organisms from the neighbourhood also settle on different parts of our body. If the conditions are congenial, they multiply fast and establish themselves constituting the native microflora of our body known as micro-biota. Each part of the human body, with its special environmental conditions, allows only a particular variety of microorganisms. Thus microbiota of one organ is different from that of the other. For example the natural microbial population of the oral cavity is different from that of the intestines. Further, the composition of microbiota of any particular organ at a particular time in ones life varies depending upon the general health conditions, diet, hormonal activity, age, hygienic conditions and other habits of an individual.

In general most of the microbiota establish an intimate relationship with their hosts and live as commensals utilizing the secretions and waste products of our body. They do not cause any harm to their hosts. Others live in a mutualistic association where both the partners derive benefit. Thus the intestinal bacteria act as scavengers using the waste materials produced by their hosts and at the same time they also synthesize some of the vitamins (B,E,K) required for the growth and well being of their hosts. The microbiota being well established natives do not allow the invasion of pathogenic organisms, foreign to the native flora. Thus the microbiota play a very significant role in maintaining the health of human beings. This protective effect can be brought about by several ways. It may be a competitive limitation of nutrition or secretion of certain substances inhibitory to the invader. For example, the lactobacilli present in vagina produce acids which prevent gonococcal infections—gonorrhea. The intestinal *Escherichia coli* produce substances called colicins which protect the intestinal tract from the pathogenic bacteria.

The skin is constantly exposed to the action of various microorganisms present in the environment. But most of them fail to grow because of the hostile environment created by the native microbiota, immunological factors of the host and inability of the foreign microbe to colonize. The sweat glands of the skin excrete lysozyme, an enzyme that destroys the bacterial cell walls. The sebacious glands secrete complex lipids which may be partially degraded by some bacteria releasing fatty acids which are highly toxic to other bacteria. Further the structural and functional variations of the skin at various sites of the body also offer resistance to these foreign microbes. At the same time, they also facilitate the colonization by certain types of microorganisms on the skin. Most of the colonizing bacteria occupy the superficial squamous epithelium (the outer layer of the skin) and live on the surface of the dead cells. Generally they are the species of the genera *Staphylococcus* and aerobic *Corynebacteria.* The anaerobic lipolytic bacteria like *Propionobacterium acne,* the cause of acne, preferentially recolonize the deep sebacious glands (Fig. 1).

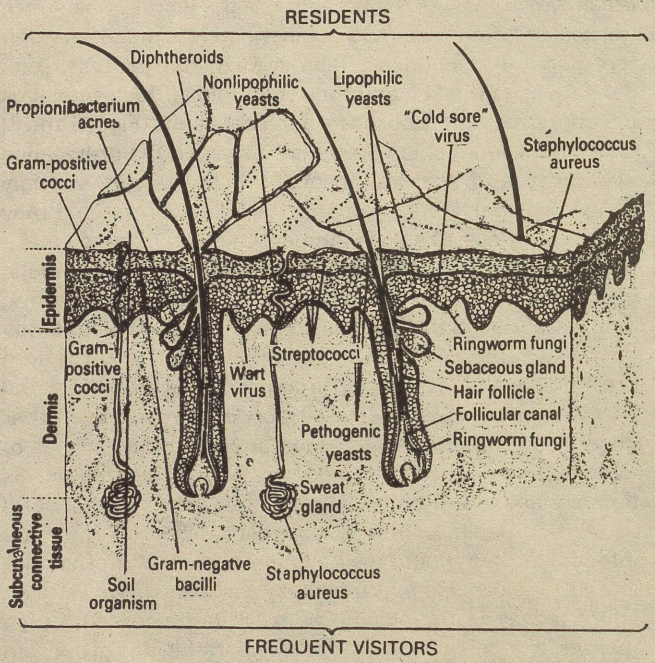


Fig. 1. Microorganisms resident in or on human skin

The oral cavity constitutes an ideal place for the growth and proliferation of numerous bacteria. The temperature, slightly alkaline reaction of the oral secretions and the presence of suitable moisture constitute a congenial situation for the proliferation of these bacteria. Saliva provides all the essential nutrients like proteins, amino acids, lipids, carbohydrates and other inorganic compounds.

At the time of birth the oral cavity remains essentially sterile. But within a few hours a number of microorganisms representing the genera *Staphylococcus, Neisseria, Veillonella, Actinomycetes* and *Lactobacillus* come to stay, and multiply forming the characteristic microflora of the oral cavity. The kind and number vary with the infant's diet except that of *Streptococcus salivarius* which due to its affinity to epithelial tissue remains adhered to the surface of the tongue from the second day of the infant's birth. With the eruption of teeth the area around them becomes anaerobic and hence anaerobic bacteria like *Bacteroids* and species of *Fusobacterium* begin to colonize. The tooth surface is also occupied by *Streptococcus sanguish* and *S. mutans.* The latter is believed to be the etiologic agent of dental caries. The glycoproteins of saliva aggregate the bacteria and bind them on the the tooth surface. The extracellular polysaccharides called dextrans secreted by these two bacteria

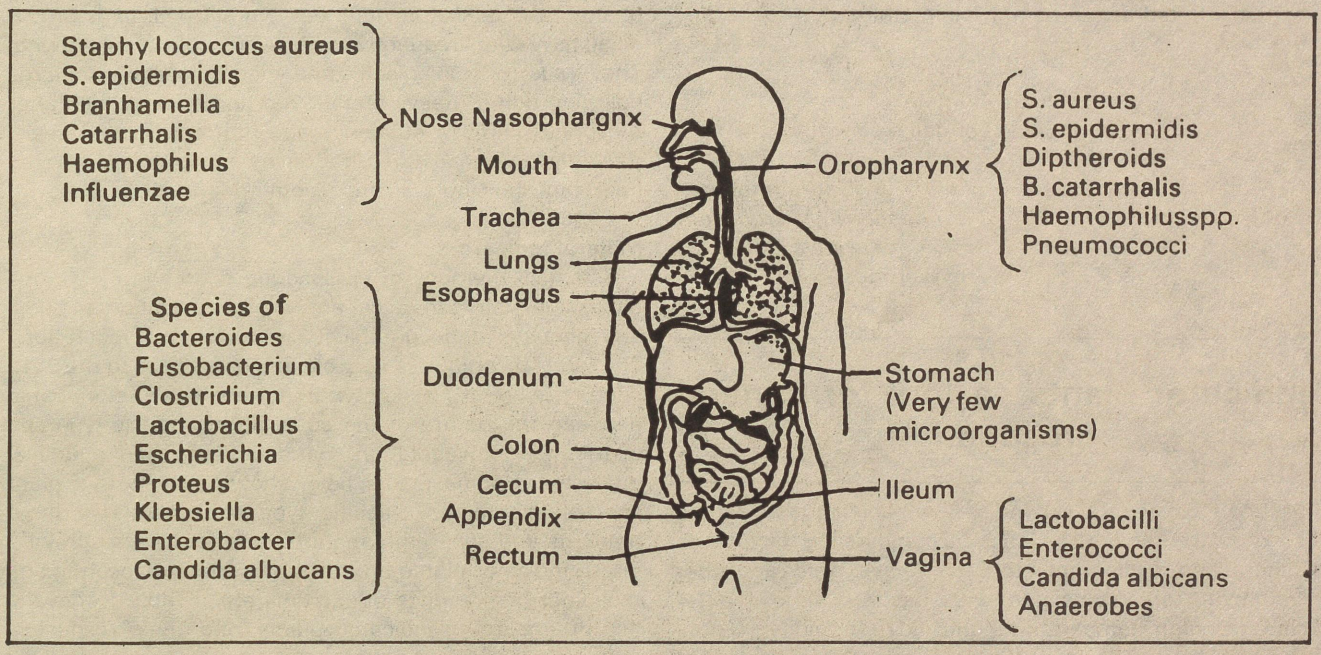


Fig. 2. Microbiota of human body

act like glue and firmly hold them on the tooth surface. They are called plaques. But continuously flowing saliva acts as a cleaning agent.

The intestinal microflora undergoes essential changes with age. The intestinal tract of a newly born baby in the first few hours remains sterile. But with breast feeding the lactic acid bacteria—*Bifidobacterium* and acidophilic bacillus, etc., develop and exhibit antagonistic properties against those causing intestinal disorders. Thus they protect the children during the breast feeding age. *E. coli* and other entericocci are also seen, the number of which sharply increases with age and mixed feeding. When breast feeding is stopped, the microflora of children's intestines also change to that of an adult containing *E. coli, Clostridium perfringens, Streptococcus faecalis* (Fig. 2), *Proteus vulgaris,* etc., *Cl. perfringens* secretes digestive enzymes while the other bacteria produce vitamins essential for the maintenance of good health. The acidophilic *Lactobacillus bulgaricus* and other antagonistic bacteria may inhibit the development of pathogenic bacteria.

Every time we breath, a large number of microorganisms are inhaled along with some dust particles. The microorganisms in inspired air are 200-500 times greater than that in expired air. But most often these are trapped in the nasal cavity and only a small amount enters the bronchial cavities. The mucous membrane of the nose produces mucin and lysozyme whose bactericidal action kills all the microorganisms adhering to the nasal mucous membrane. Nevertheless the nasal cavity maintains the microflora relatively constant. It is generally constituted of gram negative saprophytic diplococci, non-haemolytic Staphylococci, Proteus, etc. Many viruses particularly adenoviruses remain viable for a very long time without causing any pathological symptoms. The upper respiratory tract (nasopharynx and pharynx) contains a relatively constant species of bacteria namely *Staphylococcus albus, Gaffkya tetragena,* etc. They never cause pathological symptoms unless the host defensive mechanisms are weakened as a result of starvation, vitamin deficiency, etc.

In healthy persons the genitourinary tract generally remains free from microorganisms except the lower urethra of both males and females. Their number decreases near the bladder apparently because of the antibacterial action of urethral mucosa and also frequent flushing of its epithelium by urine. In a two day old baby the genital tract remains sterile or may contain a few gram positive bacteria and some cocci. But in adults the situation becomes complex. The population characters change with variations in menstrual cycle. The vaginal contents of healthy women have relatively high concentration of sugar and glycogen and low content of diastatic enzymes and proteins. The pH is highly acidic (4.7) and some anaerobic bacteria, *Candida albicans* and *Lactobacilli* capable of multiplying at this low pH alone can be seen (Fig. 2). The acidic nature of vagina depends on the presence of glycogen secreted by the vaginal epithelium while the accumulation of glycogen is governed by the ovarian activity. Therefore it is not present before puberty nor after menopause. The glycogen under the influence of vaginal bacteria is transformed into mono and disaccharides and then into lactic acid. The vaginal bacteria with their antagonistic properties ward off the disease causing microorganisms.

Thus every part of the human body is guarded by the invisible biological soldiers—the native microbiota, which

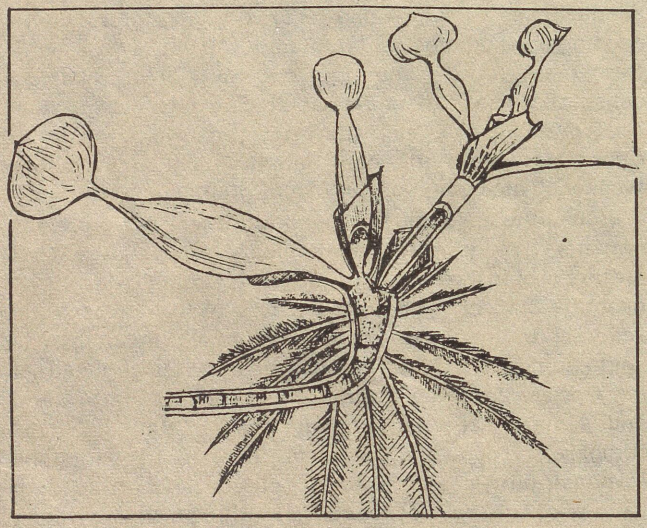
by their united action help in maintaining our health and teach us,

United you gain
Divided you fall.

A. Subrahmanyam
Reader in Microbiology
Kakatiya University
Warangal-506009 (A.P.)

Indicator plants—a tool for mineral prospecting

PLANTS in general can indicate a deficiency or an excess of water and often such accompanying factors as mineral and salt content, etc. *Cacti, Agave, Yucca* and other xerophytes are associated with habitats of low water content, high temperatures and low humidity. Cattail *(Typha)* water hyacinth *(Eichhornia)* and other hydrophytes indicate an excessive water supply and poor aeration.



Avicennia, Rhizophora, Atriplex and other halophytes denote an excess of soil solutes and mineral salts. The fossils of these plants can undoubtedly indicate the environment in which they flourished in the past. Plants having distributions which correlate well with the content of some element in aquatic or terrestrial habitats are called indicator plants. They are used in monitoring water pollution and in the prospecting for ore deposits.

Water pollution indicators

Algal blooms are indicators of certain mineral enrichment in an area. Several research works have established the feasibility of using benthic algae as qualitative or quantitative indicators for heavy metal pollution. Brown algae have been frequently employed for coastal monitoring. They react physiologically and morphologically towards pollution due to heavy metals and herbicides which alter the photosynthetic efficiency and nutrient uptake levels. *Ascophyllum nodosum* and *Fucus vesiculosus* are the important indicators of zinc, cadmium and copper.

Mineral indicators

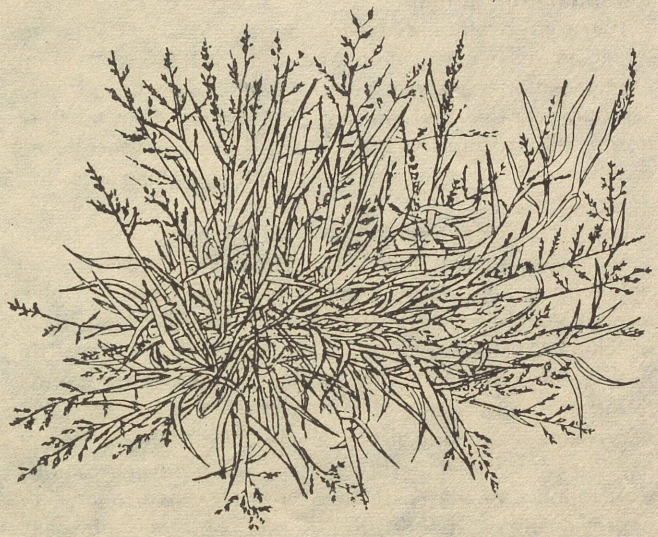
Botanical methods of prospecting for minerals include biogeochemistry (chemical analysis of vegetation and soil) and geobotany (geographical distribution of vegetation). The latter technique is very old and dates back to the 17th century; when it was known that there was a relationship between the nature of the substratum and the type and distribution of vegetation. Sand cultures and chemical analyses of some plants have shown that certain plant species accumulate specific type of minerals in large amounts and apparently require them for healthy growth. These indicator plants are, thus, important in locating and mapping the presence of such minerals. Table 1 shows a list of important indicator plants and their respective minerals.

Table 1. Some minerals and their indicator plants

Minerals	*Indicator plants*
Aluminium	*Hydrangea Macrophylla*
Barium	*Anthoxanthum odoratum*
Bromine	*Allium cepa*
Calcium	*Medicago sativa*
Chromium	*Nicotiana tabacum*
Cobalt	*Nyssa sylvatica* & *Andropogan virginicus*
Fluorine	*Chenopodium murale* & *Poa annua*
Iodine	*Lactuca sativus*
Lithium	*Citrus* & *Poppy*
Nitrogen	*Persea americana*
Selenium	*Astragalus albulus* & *A. Argillosus*
Strontium	*Arabis stricta* & *Carex humilis*
Vanadium	*Amanita muscaria a fungi*
Zinc	*Ambrosia artenaisiofolia*

The most interesting indicator plant for aluminium is *Hydrangea macrophylla* which produces blue flowers if aluminium is available in the soil, but pink flowers in the absence of the element. The important indicator plants for copper are *Haumaniastrum katangense* and *Becium homblei*. These cuprophytes are found exclusively on soils containing more than 5000 μg of copper per gram soil. They were used extensively in the 1950s for copper exploration because geobotanists noted that they never grew in soils containing less than 100μg copper per gram soil. *Chenopodium murale* and *Poa annua* are the best indicator plants for fluorine in soil. These plants are useful to diagnose fluoride air pollution as they develop characteristic foliar symptoms of fluoride injury.

Geobotanists rely strongly on the identification of plant



species or plant communities specific to certain types of mineralization and their task becomes much easier if an indicator plant can be identified. The remarkable distribution of *Haumaniastrum katangense,* a copper indicator has led to interesting archaeological discoveries in Zaire. The ancient copper mines of Zaire are identifiable by dense carpets of *H. katangense* or *H. robertii* which grow over them even now. Wide explorations are further needed in the field of indicator plants to unearth hidden resources like minerals, fossil fuels, etc., and also to forecast volcanoes and polluted areas.

P. Kaladharan
Scientist, Central Marine Fisheries Research Institute
Cochin-682031

Beware of tannin-rich animal feed

IN India, considerable quantities of unconventional tannin-rich animal feed is consumed by livestock. This adversely affects the assimilation of nutrients, especially protein, by the animals. When free tannins escape into the blood stream, they cause damage to certain vital organs too.

The tannin content of tree leaves varies from zero as in *Grewia optiva* ('biul' in Hindi) to 7.6 per cent in *Syzygium cuminii* ('jamun' in Hindi). Generally, a decline in the digestion of protein is noticed with increase in tannin content. But in *Aegle marmelos* ('bel' in Hindi) with 2.2 per cent tannin, protein digestion rose to 71 per cent.

The tannin content of dry beans ranges from 0.045 per cent (as in soya beans) to 2.0 per cent (faba beans). In the case of dry beans, the tannin content is dependent on the colour of the seed coat or testa. White seed varieties are therefore found to contain no detectable amount of tannin, while coloured seed varieties contain large quantities of tannins. Tannin content is higher in black grams, faba beans, peas and pigeon peas.

Studies on the utilisation of agro-industrial products as a feed to livestock have been in progress in India for over three decades. A number of by products have been found useful as unconventional feed ingredients. Owing to the abundance of sal seed meal, it has attracted maximum attention and has been widely recommended for incorporation in the rations of cattle, poultry and pigs. According to a recent estimate, the total area under sal trees in india is about 114,000 sq. km and the total yield of sal seed kernel would be of the order of 5,650,000 tonnes, if the entire quantity were collected. Sal seeds, especially collected to serve as a source of sal fat, is edible and can also be put to various uses, for instance, as an extender for cocoa butter and as hard fat in soap manufacturing processes. The chemical composition of deoiled meal is almost similar to that of cereals like barley and oats. However, the starch content is associated with a high proportion of tannins (6.2 to 13.7 per cent) and lignin content.

Feeding varying levels of sal seed meal to different animals causes a decline in nutrient availability since the digestion of its nutrients especially proteins is considered lower.

Several studies have shown that there is a progressive deterioration in weight of chicks when fed with sal seed meal. The fall in growth was only slightly counteracted by supplementation of extra protein through groundnut cake and, also, when sal seed meal is treated with alkali, 64 per cent of the tannin can be removed.

Vegetable tannins are water soluble phenolic compounds with molecular weights between 500 to 3,000. They have special properties such as the ability to precipitate alkaloids, gelatine and other proteins and affect the digestion of dry matter and utilisation of nutrients. Tannins are divided into two classes—hydrolysable and condensed tannins. The former, with a specific acid or alkali, can be hydrolysed to sugars and gallic or ellagic acid. Condensed tannins, on the other hand, do not readily break in this manner.

Tannins have been found to influence the metabolism of ruminating animals. Reduced urease activity, protein degradability, volatile fatty acid production, microbial DNA (deoxyribonucleic acid) and RNA (ribonucleic acid) are observed in ruminants with increase in tannin concentration of diets. Tannin-rich diets cause degenerative changes in liver, kidney, spleen and intestines. Presence of mucous threads and albumen in urine and irritation of the urethra have also been observed, when the intake of tannins is large.

Therefore, it is imperative that the composition of such tannin-rich feed is assessed in detail and a solution found for their useful incorporation in the diet of domesticated animals.

C. Lalitha
Bombay based
Science Writer

Aggressive behaviour

CHARLES Darwin believed Natural Selection as the most important biological phenomenon of organic evolution and regarded sexual selection as the prime mechanism for the survival of the best adapted species of animals. He thought that the acquisition of property and fixed abode, union of several families under a chief and sexual behaviour are the primary requirements for social evolution and civilisation of human beings. The human species has certainly survived through its sexual behaviour but the method of obtaining a partner for the continuance of the life chain is highly competitive and even combative in many societies. Again the human being is highly vulnerable and so he must defend itself against its abiotic and biotic environment. In course of evolution, man became terrestrial and carnivorous and consequently switched over from retreating to attacking pattern. This chain of events during social evolution of the human being gradually leads him to the expresssion of a characteristic behavioural pattern —'aggression'— for his survival. Clinical history has shown that man becomes aggressive when he gets perturbed and alarmed.

Definition and manifestation

It is difficult to define aggressivity as aggression takes a variety of forms. There is no definite organ for its expression. A whole range of behaviour from nail-cutting through verbal insult to suicide is the manifestation of aggressive behaviour. It has been found that female macaque become markedly aggressive after being treated with a large amount of oestrogen. But the result of such experiments still remain inconclusive. In our culture, aggressive role is the man's domain. In man androgen, the male sex hormone, tends to promote aggression, but oestrogen, the female sex hormone, has no such effect in human female. However, psychic aggression appears both in man and woman.

During aggression the subject experiences a great deal of physiological changes in its organism. In human beings, heart beat gets accelerated, pupils of eyes become dialated and sweat glands function excessively. Normal function of the body like urination, defecation and salivation are inhibited. When the subject is in aggressive mood he or she assumes certain postures towards the opponent or imaginary opponent. However, the usual pattern in aggressive exchanges is often ritualised in such a manner that severe physical injury among the combatants is avoided. During aggression various threat postures are assumed and abusive languages (vocalisation in animals) are employed indicating the readiness to attack. But the actual fight rarly takes place. Aggressive exchanges cool down when one of the combatants assumes submissive posture and/or leaves the arena.

Hereditary or learned?

There is no authentic record to indicate the degree to which aggressive behaviour is determined by constitutional predisposition passed on to human beings by ape-like ancestors or learned through frustration, fear, anxiety during the life-time of the subject. However there is no group of animals or human beings free from frustration and aggression.

Laboratory experiments with rats and mice have shown that aggression has a clear genetic make-up. The courtship and mating behaviour of many fishes and birds involve intense aggressive behaviour. In an experiment, eggs from stickleback fishes were reared in complete isolation. The new generation of stickleback fishes were subsequently found to acquire and maintain territories with typical aggressive behaviour of the species. In another series of experiment for selective breeding in fishes and game fowl it was found that they exhibited higher or lower degree of aggressiveness. In short, the animal population normally carries many genes which would cause aggressiveness. The selective breeding in animals could therefore, change their aggressive behaviour either way. So the potential to aggressiveness has an inherited basis and should be regarded as a biogenetic act.

In human beings, aggressive behaviour accompanied with bodily injury and abusive language (sadism and masochism) during courtship and sexual performance are reported in clinical literature. Again, the tendency to aggressiveness has been found in many children as a part of genetic endowment accompanied with destructive activities from their infancy. Nobel laureate and celebrated ethologist Konrad Lorenz observed that aggression in man is related to his biological past, i.e., aggression both in human beings and animals is the result of an inherited tendency similar to the biogenetic drive to eat and drink. The noted psychologist Alfred Adler has suggested that aggression is a universal overcompensation for feeling inferior and insecure. But some other ethologists feel that though it has an inherited basis, aggression is not inevitable in human beings. They feel that its expression depends upon experiences, external factors, fear, anxiety, etc. On the other hand, over population in an area (space shortage) also leads to aggressive behaviour in individuals. Among the children it may be provoked by pain, punishment, restriction of mobility, deprivation of nutrition, warmth and withdrawal of love. Frustration in daily life also such as in a traffic jam promotes aggression.

Many mature animals as well as men avoid physical contact with others. Individuals living with others in the same house, apartment or room require some seclusion from others at some period of the day. If such a requirement is denied for a long time he or she resorts to aggressive behaviour on slightest provocation. It is found that too much congregation in a place or increase of population density in an area brings about 'social stress' among the individuals. Pituitary and adrenal glands respond to stress and get considerably activated causing exhaustion in the subject.

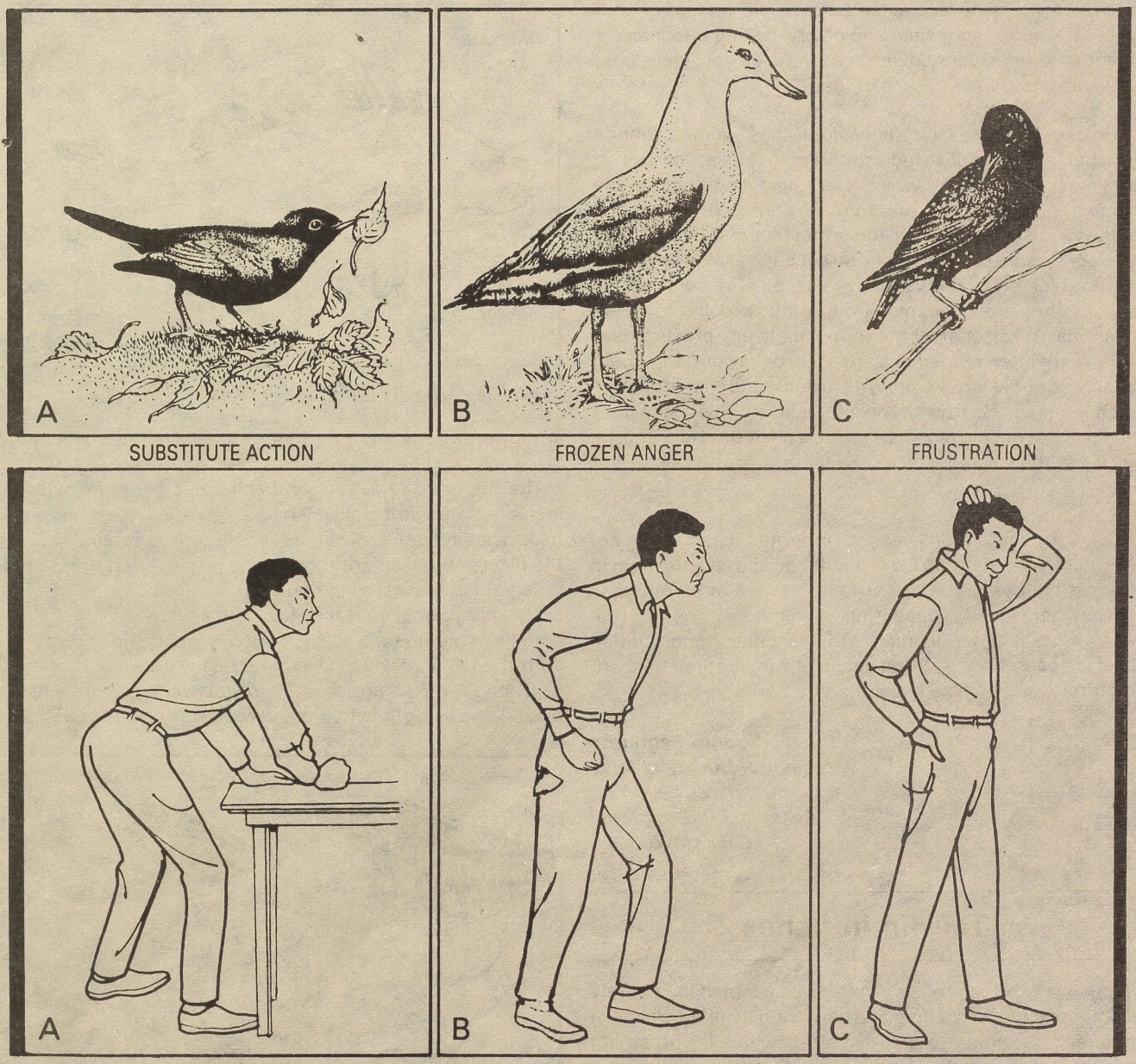


Fig. 1. Expression of aggressive behaviour and its substitute activities in bird and man. (a) A starling releases its feeling of aggression by pecking vigorously at a leaf instead of at a bird; in the same situation the man will react by banging his fist on a substitute target like a table: (b) Here a gull stands ready to peck the rival but fails to do so; the aggressive man clenches his fist and takes a step forward towards his rival. (c) When facing a rival a starling may preen its feathers instead of fighting; in a similar situation a man may scratch his head in frustration

This exhaustion leads to hyperglycemia, adreno-cortical hypertropy, decreased liver glycogen, deposition of lipid in liver. It also decreases chloride in blood but raises the proportion of potassium leading to several disorders. In this situation both animal and human beings break down and then aggressiveness increases exponentially.

The living conditions of a person and the nature of his upbringing in a family also lead to aggressive behaviour. In an experiment, college students were tested under conditions in which their answers were invariably declared wrong. Due to frustration two groups emerged: (a) those who resorted to self-blame and anxiety mainly secreted a high level of adrenalin; and (b) the others who converted their frustration into anger and aggression mainly secreted nor-adrenalin. This difference in behaviour neatly matched their social background. The first group of students had come from protected home environment and the second were the denizens of slum where aggressive behaviour was

a pre-requisite to social and economic success. Early experience therefore seems to have a lasting effect on the manner in which our bodies are physiologically developed to combat various stresses of life.

However, aggressive behaviour has some definite function in the life of an individual. For instance, aggression prevents actual fight which may lead to injury to the combatants. Almost in all animals and man, aggressive behaviour is a weapon for the protection of their territory. The aggressive behaviour of a street gang is also related to its concept of territory. Aggressive posture with verbal abuses often protect women from being sexually harassed. In animals, protection of the young, mate and procurement of food are often related to aggressive behaviour. In human culture, aggression is employed to dominate over others for social status. Scores of people employ this behaviour pattern as a means of gaining status, position and authority either in their home, place of work or any other aspect of life.

Though aggression has an inherited basis it is not inevitable. The long period of childhood and development in human being and the powerful influences of parents and society, education, upbearing eliminate or reduce the aggressive potency in man. On the other hand, human species possesses a strong sense of cooperation. In short, man reflects his mixed evolutionary heritage.

Sudhin Sengupta
Zoological Survey of India
Nizam Palace, 13th floor
Acharya J.C. Bose Road
Calcutta-700020

Tail-fin in fishes

A fish may be defined as a vertebrate adapted for a purely aquatic life, propelling and balancing itself by means of fins, and obtaining oxygen from the water for breathing purposes by means of gills. The fins, which form so characteristic a part of the fish, are of two kinds, median (or unpaired) and paired. Pectoral and pelvic fins are paired, whereas a dorsal fin in the middle line of the back, an anal fin on the belly behind the vent and a caudal or tail-fin at the hinder end of the fish are median fins (Fig. 1).

Tail-fins are of three major types in adult fishes. The fin in sharks is the heterocercal type (Fig. 2). In sharks, the posterior part of the vertebral column is bent upward and continues almost to the tip of the fin resulting in two lobes of the fin—the small upper lobe and a much larger lower lobe. Thus, both internally and externally, the two lobes of the fins are asymmetrical. The heterocercal fin is also found in many placoderms, the archaic fishes now entirely extinct, and among bony fishes, the ancient ray-finned

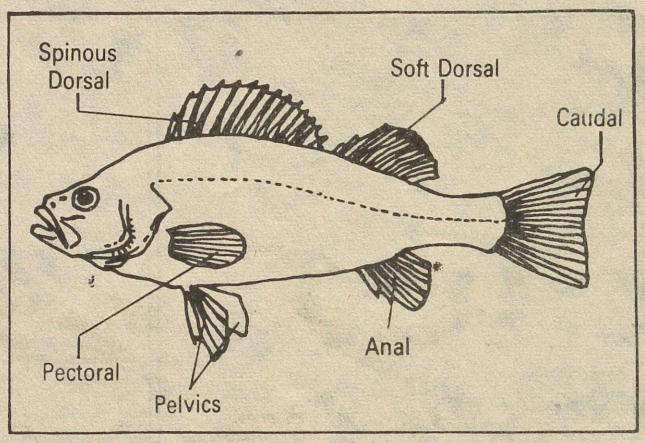


Fig. 1. Topography of fins

group represented by fossil forms the palaconiscoids and living forms, the sturgeons and the paddle fish.

The fin, where the vertebral column is bent downward instead of upward unlike sharks, is called the reversed heterocercal type. It is seen in some otracoderms (Fig. 2), the oldest and most primitive of the fossil vertebrates, and in larval lampreys, the serpent-like jawless fish.

The diphycercal fin is the second major type in which the vertebral column runs straight outward to the tip of the tail, with the tail fin developed symmetrically above and below it. Good examples are seen in *polypterus,* a primitive fish (Fig. 2), the living lung fishes and coelacanth, the *Latimeria.*

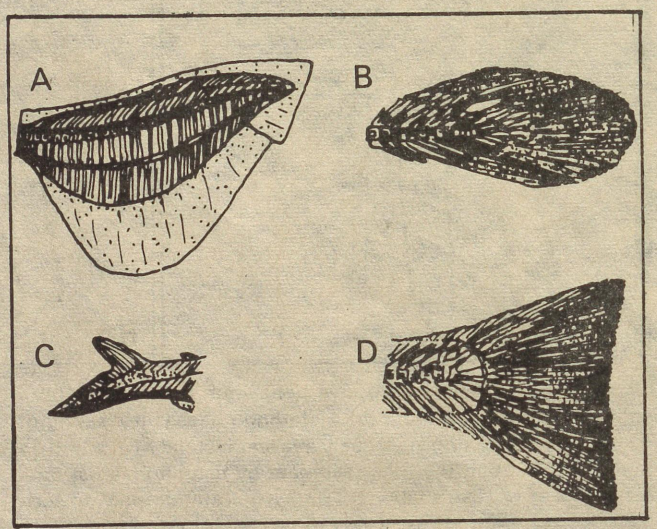


Fig. 2. Caudal fins—(A) Heterocercal type seen in sharks, sturgeons, paddle-fish; (B) Diphycercal type seen in Polypterus; (C) Inversed heterocercal type seen in Ostracoderms; (D) Homocercal type of teleosts

The third major type is the homocercal fin characteristic of the dominant modern fishes, the teleosts (Fig. 2). This is superficially symmetrical. Internally the hinder end of the vertebral column turns upward but unlike the heterocercal

condition it does not reach the innermost limit of the fin. Among bony fishes, the shape and size of the caudal fin exhibits a good deal of variation (Fig. 3). Fins may be described as lunate as in Thunnus; forked as in Mackerel; emarginate as in carps and perch; truncate as in Flounder; rounded as in Turbot and lemon sole and pointed as in Goby.

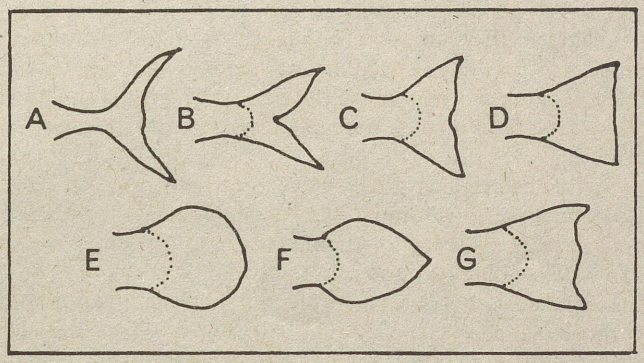


Fig. 3. Shapes of Caudal fin (A) Lunate; (B) Forked; (C) Emarginate; (D) Truncate; (E) Rounded; (F) Pointed; (G) Double emarginate

The shape of the fin provides a good index of speed and agility. As a general rule, fishes with a lunate or with deeply forked caudals are capable of sustained swimming at a high speed, while those with squarish or rounded caudals, are capable of sudden bursts of speed, but on the whole are comparatively slow swimmers.

The tail-fin is absent in some fishes as in the case of the Sea Horse *Hippocampus,* the Eels (Anguilliformes) and a few other fishes. The Deal fish *(Trachypterus)* and Sun-fish *(Mola)* have unusual tail-fins. In the Deal fish, the fin is directed upwards at right angles to the long axis of the body, while in Sun fishes the body ends abruptly and is margined by a low rounded caudal with a slightly wavy edge (Fig. 4).

Two primary methods are employed by fishes to produce

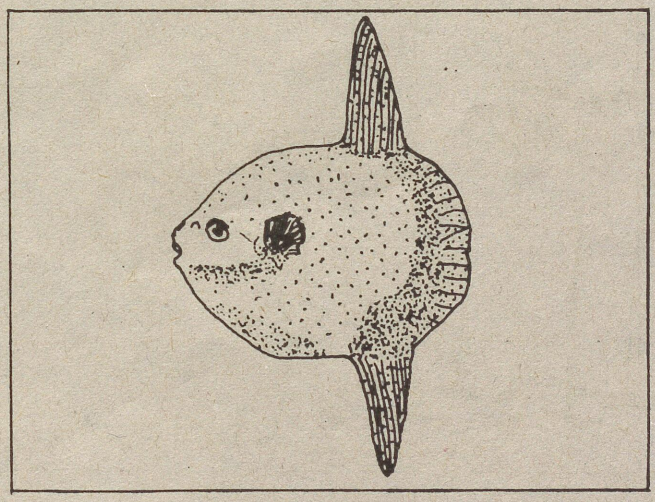


Fig. 4. Sunfish (*Mola mola*). It has a circular and somewhat compressed body and the tail is rounded

forward movements in a fluid medium: (1) body movements by alternate expansion and contraction of the body muscles, and (2) by movements of the appendages (fins). It has been remarked that the caudal fin is operated primarily by the action of the muscles of the body and tail, but many fishes are capable of moving slowly forward by means of wave-like movements of the fin itself, the waves travelling at right angles to the longitudinal axis of the body.

In a typical pelagic fish, the development of tension in the muscles on one side of the body tends to rotate both the head and tail towards that side. Owing to its large size the anterior end only moves laterally to a limited extent, but the tail is swept towards the side contracting. The forces operating on the tail have both lateral and forward components. As it moves to the left, the resultant force acts forward and to the right, and vice versa. Thus, during a complete cycle of tail movements, the forces to the left and to the right cancel out, whilst the forward components overcome the drag exerted on the body by the external medium and propel the fish forward (Fig. 5).

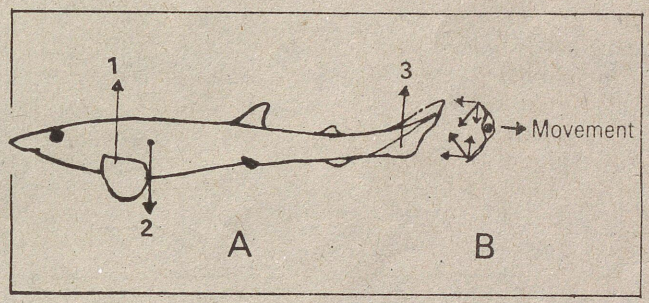


Fig. 5. (A) Lateral view and (B) Transverse section of the tail of a dog fish showing the role of the tail and fins in generating lift and providing stability: (1) Lift from pectoral fin, (2) Centre of gravity, (3) Lift from heterocercal tail.

Since structure is the integral part of any function, the fish movement correspondingly depends to a great extent on the varied structure and shape of its caudal fins.

The sharks, whose specific gravity is greater than that of water, have a characteristic heterocercal tail. As the tail sweeps from side to side its leading surface, the large lower flap, is directed obliquely downwards and backwards so that the water exerts an upward pressure that tends to raise the tail during motion. This upward force at the tail tends to depress the head and the tilting effect about the centre of gravity is counteracted by the set of horizontally placed and relatively inflexible pectoral fins against which water also exerts an upward pressure. Thus, we see that the paired fins act to elevate the anterior of the body and the posterior of the body is elevated by lift generated by the heterocercal tail. The fish will sink if it stops swimming. The combined effect of the forces on the pectorals and tail is therefore to raise the fish vertically in the water, and during locomotion at constant depth, these two sets of upward forces exactly balance the body weight.

Thus, a facility to maintain a uniform depth would be of utmost importance to species such as the whale shark, mackerel shark etc., which range over the deep ocean. It is of less significance in dogfish that inhabit shallow waters and therefore can rest on the sea-floor. In some, such as the basking shark, their density is very close to that of the sea water (due to the presence of lipid and hydrocarbon, particularly in the liver). Thus, their pectoral fins do not have to produce such appreciable vertical forces in order to maintain constant depth and their use is restricted to manoeuvering.

In contrast, the more advanced bony fishes have evolved a swim bladder, an air sac dorsal to the body cavity that has greatly reduced the problems of lift. The swim-bladder confers upon the fish a density equivalent to that of the surrounding water at a particular level. During fast swimming, typical teleosts keep all their fins, other than the caudal ones, folded flat. They are only brought into use to counteract any forces tending to displace the animal either upward or downwards, but are relatively unimportant in the maintenance of a horizontal cruising plane. Spreading the vertically inserted pectoral fins at right angles to the direction of motion, provides a very effective braking action.

In the eel-like fishes (where the caudal fin is reduced or absent), the anterior part of the body is cylindrical in cross-section, whereas the hinder part is distinctly compressed. This feature has a mechanical advantage, since a blade-like structure which presents its surface more effectively to the water naturally provides a greater amount of thrust than a rounded one. Thus, mechanically, this part of the eel's body functions like the expanded caudal fin of other fishes. The Seahorse (tail is used as a prehensile organ), swims in an upright position and glides slowly through the water by means of rapid wave-like movements passing along the dorsal fin, which has the appearance of a tiny propeller revolving in the mid dorsal region of the fish. The round tailed sun-fish has a circular and somewhat compressed body, looking as though the tail end had been amputated (Fig. 4). Such a body is probably well adapted for passive drifting.

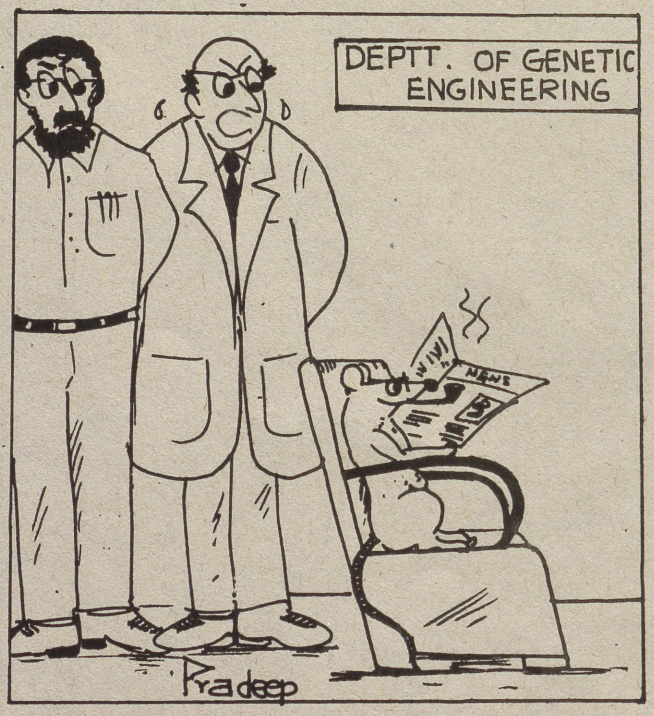
In many tetrapods which have returned to an aquatic existence, as in seals and turtles, the limbs rather than a tail act as a propulsive organ. Aquatic mammals, the Cetaceans like whales, dolphins and sea-cows too have a tail-fin, but this consists of horizontally expanded flukes or lobes unlike vertically placed lobes found in fishes. The extinct ichthyosaurs (aquatic reptiles) have come closest to the redevelopment of a fish type of tail, expanded vertically and supported by the vertebral column.

Vijay Mala Nair
Pool Officer
College of Fisheries
Mangalore-575002

CARTOONS BY *P.K. Srivastava*



"What is this? I am incharge of communication. Why I was not informed about this conference?"



"Something wrong? He refuses to go back into the cage, wants salary, DA, ADA, House rent, etc., etc."

How water balance is maintained in plants

IN living organisms about 80 to 90 per cent of the fresh weight of fully hydrated tissue is water. 400 hundred million years ago, life was first created in water in the form of a single cellular structure and with passage of time, complex multicellular terrestrial organisms evolved. This evolution was possible as the cellular biochemical system, which operates in aqueous medium, attained perfection gradually. Inside the cell, water pervades all portions of the cellular organelles and works as a medium for the chemical reactions, which sustains life. Mineral nutrients are absorbed and transported from one part of another in water. Water unites the substrates with the enzymes and biochemical reactions in the cell are effected. Energy transduction in the cell, which is so essential for life requires water as the medium. For many biochemical reactions water is a reagent. It is a substrate for photo-synthesis and breakdown of complex carbohydrates, proteins and lipids, whereas it is a product of respiration. Biological macromolecules, such as proteins or nucleic acids exist in their secondary spiralled structure due to the formation of hydrogen bonds in the aqueous medium. If water is withdrawn, these weak hydrogen bonds break and the macromolecules are denatured. The enzymes which are big proteinaceous macromolecules loose the potential for biological action when desciccated. Thus, structural integrity of macromolecules which is essential for biological action, is stabilized, when they remain associated with water molecules. The other important function of water is growth, which is possible through cell division or elongation or both. Unless the cell membrane is stretched by the hydraulic force of water due to a positive turgor pressure, both cell division and cell elongation are not effected. Thus, life is only possible in water and water cannot be replaced by any other known liquid. Life is only possible in water because of its extraordinary physico-chemical properties such as, high specific gravity, high heat of fusion, high specific heat, high heat of vaporisation and greatest surface tension amongst the other known liquids. The molecule is small to permit easy movement and its dipolar nature enables it to dissolve both anions and cations with equal affinity.

Water in the biosphere and plants

Nearly three fourth of earth's surface is covered with water. The oceans and other land-locked reservoirs contain 1.5 billion cubic kilometers of water. Out of this, the oceans and seas hold about 97% which is salty and poor in essential nutrients required for plant growth. Of the rest three, two per cent is not accessible to the living organisms, being locked in the frozen ice caps of mountains and polar regions of the earth. Therefore, although earth surface abounds with water, the actual amount available to the terrestrial plants, animals and microbes is one per cent of the whole. The terrestrial water remains in the rivers, lakes and underground reservoirs. A part of it is converted to gas and remains in the atmosphere. Since water has been so vital for life and only a very small portion of the available whole has been placed at the disposal of the land dwelling organisms, it is the most essential ecological factors which determines flora and fauna of a particular habitat.

Plants remain stationary and fixed to a particular habitat throughout their life and absorb water from the soil by their roots. The moisture content in their cells remains in a state of dynamic equilibrium with the environment and fluctuations in environmental factors influence water movement between the two. Although provision of water has been very essential for the plants, most of the absorbed water is lost into the atmosphere in the form of evaporation through stomata, cuticle and lenticels. This is because, the primary form of nutrition of the autotrophic green plants is gaseous (absorption of CO_2). When the guard cells of the stoma open to fix CO_2, the moisture saturated stomatal cavity comes in contact with the atmosphere and transpiration occurs. For movement of water in and out of the plant, energy is necessary. Therefore, the direction of movement is determined by the gradient in potential energy of water (measured in the units of bars of pascals) present between the plant cells and the environment.

Water moves from the region of high to that of low potential. The potential of pure water is zero. The energy content of water decreases when solutes are dissolved in it. Thus, plant cell sap or soil solutions containing many types of solutes have negative water potential. When free water content of the medium decreases with the intake of more solutes, the potential to do useful work decreases and water potential becomes more negative. Thus, when the atmospheric moisture content decreases due to rise in temperature, aridity or wind action, the gradient in water potential between air and the stomatal cavity increases resulting in high rate of evaporation. Water balance in plants.

Barring a few occasions during the rainy season, the atmosphere never remains saturated with moisture and gradient in water potential remains favourable for transpiration. When water loss exceeds that of absorption, the plant is subjected to a stressed condition. Deficiency of water in the lithosphere (soil environment), leading to decrease in absorption, can also impose water stress. However, in plants there has been a tendency to maintain internal constancy by conservation of adequate moisture. This has been an essential feature with the migration of plants from the aquatic to the terrestrial habitat. The plant regulates uptake and evaporation of water in response to the fluctuations in the environmental conditions. This regulation is a homeostatic mechanism which acts as a buffer to protect the plant against the environmental stress within certain limit. Each and every form of life on earth is endowed with atleast some form of homeostatic control to maintain internal constancy of its cellular system with respect to water, pH, organic solutes, electrolytes

concentration, etc., despite the abnormal conditions of the surroundings. The organism dies when the stress in the environment becomes very severe and homeostatic control fails to cope with it.

As far as water balance in plants is concerned (Fig. 1), growth stops when a plant loses too much water in the form of evaporation or internal solute concentration increases substantially. In such condition, cell water potential becomes more negative and synthesis of various organic materials such as polysaccharides, proteins, chlorophylls ceases to occur. The amino acids utilized for protein synthesis and generated due to proteolytic activities are converted to proline and the concentration of this amino acid increases rapidly. In addition to this, soluble stabilize the secondary and tertiary structures of the proteins. The protein molecules unfold exposing the sulphahydryl groups of the sulphur containing amino acids. Interchain disulphide bonds are formed in these positions leading to aggregation and precipitation of the proteins. Unless the plant has sufficient power to reduce the interchain disulphide linkage and separate the protein chains, the situation is irreversible and leads to permanent injury and death.

On the other hand, absorption of water increases its potential inside the cell and the cell becomes fully turgid. ABA concentration decreases and concentration of growth promotive hormones like Cytokinins and Gibberellins increases. Proline concentration decreases and amino

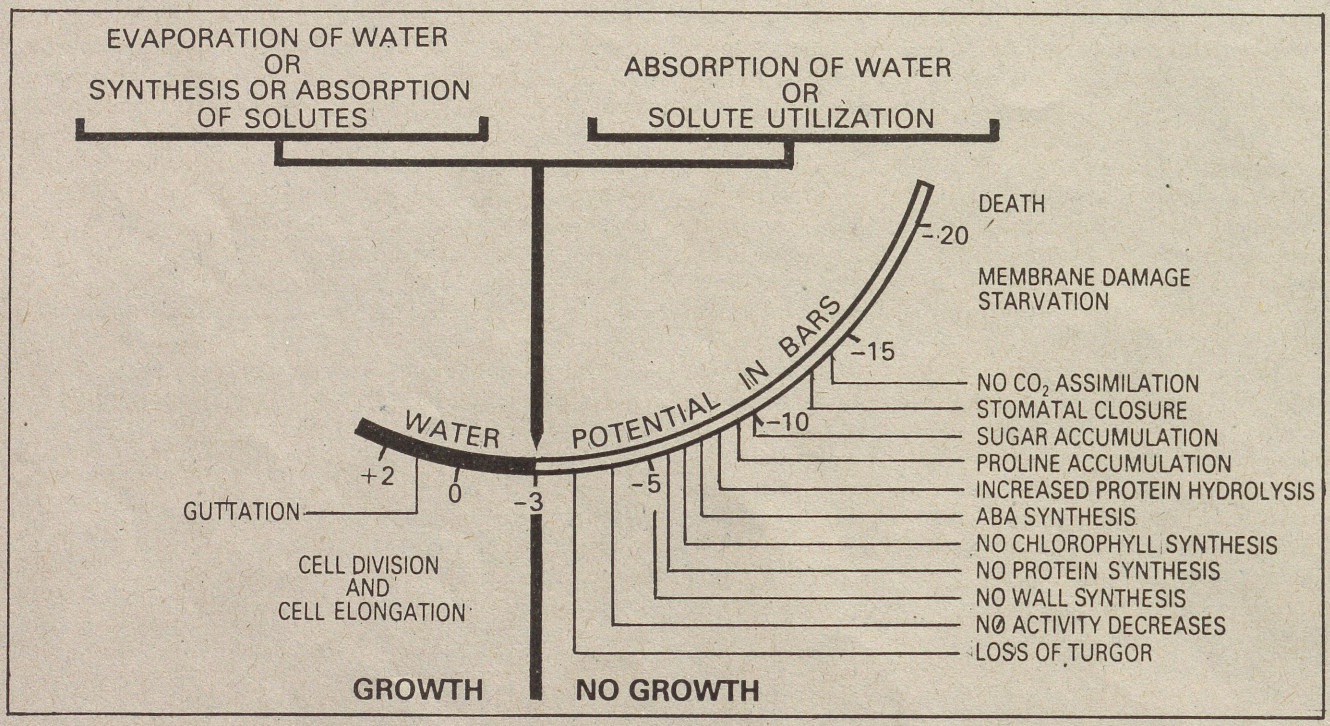


Fig. 1. Water balance in plants (Mesophytes), a homeostatic mechanism

carbohydrates and some other organic solutes accumulate to increase the osmoticum of the cell sap; and evaporation of water from the plant is reduced. Water stress induces synthesis of a hormone, named abscisic acid (ABA), which is a growth retardant. The concentration of this growth regulator increases sharply and it significantly reduces water loss from the plant by inducing closure of the guard cells. The plant gets a chance to recover normal water status through slow absorption. However, if water loss continues unabated through the cuticle and lenticels, cell water potential is reduced severely leading to membrane disruption and leaching of essential metabolites. Due to loss of turgor force (flaccid condition) protoplasm shrinks and soluble globular proteins (mostly enzymes) come in contact with one another. Low water potential weakens hydrophobic associations and hydrogen bonds which acids are synthesized. The guard cells open and the plant utilizes atmospheric CO_2 for photosynthesis. Synthesis of new wall materials, proteins and chlorophylls occur and growth is effected due to cell elongation and duplication. Too much absorption develops a positive water potential (as turgor pressure becomes high) and many plants lose water by guttation under such circumstances to relieve the extra pressure. The type of water balance is mostly applicable to mesophytes. There have been instances, especially amongst xerophytes and halophytes, where the plant survives water potential as lower as —100 bars (Desert shrub, *Atriplex nuttalli,* —103 bars).

P.K. Mohapatra
School of Life Sciences
Sambalpur Univ., Jyoti Vihar
Sambalpur-768019

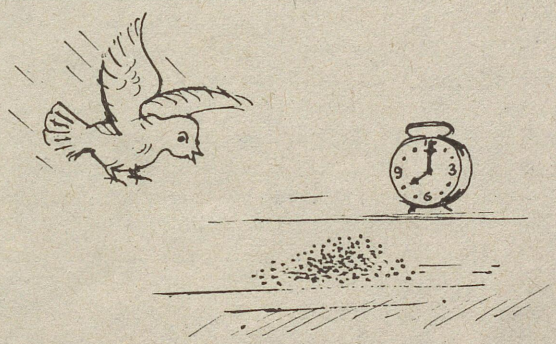
IN BRIEF

by **Hasan Jawaid Khan**

Tea can substitute for engine oil!

A new lubricating mixture uses ingredients ranging from Coca Cola to well stewed tea and even human urine. However, what makes the lubricant actually work are the additives with which such ingredients are mixed. The new lubricating mixture, named Keekote, has been developed by Dr Jack Schofield of Liverpool Polytechnic in England, and Dr Josef Fodor, an Hungarian industrial chemist.

The lubricant has been tested in 6,000 vehicles and found fit to substitute for engine oil. Its formula is however a secret. But it is thought that it is a product of the phosphoric acid of the cola on the tannin in the tea mixing with a metal organic complex.



Birds with a sense of time?

KARL Von Frisch won the Nobel Prize in 1973 for showing that bees have a sense of space and time. Now German scientists at the Max Planck Institute of Ethology along with scientists at the Edward Greg Institute of Oxford are testing birds to see whether they have a sense of space and time. They carried out experiments with warblers, a species of insect eating bird, to find out whether they can grasp the significance of varying feeding times at different places.

For this, a small home with a central living room and four adjoining dining rooms were built for the warblers. Each dining room had a feeder on which food was served. To begin with lights were switched on in all the rooms at 6 a.m. but breakfast was served in one room only. From 9 a.m. food was served in the next room. Similarly, further meals were served in the third room from 12 noon to 3 p.m. and in the fourth from 3 p.m. to 6 p.m.

At first, the warblers got their timing and directions right only about one time in four. But after a week all birds achieved a success rate of about 80 per cent. Further studies showed that the warblers had indeed understood the sequence and made a note of what to remember.

Safer wrinkle-free fabrics

WHEN wrinkle-resistant cotton fabrics hit the market for the first time they were an instant hit. No surprises, since it freed the users from the tedious task of ironing their clothes; just wash them and wear them. But the formaldehyde used in such fabrics was shown to cause cancer in animal tests. It was a potential risk for both textile workers who apply the finishes to fabrics and garment wearers who are exposed to formaldehyde vapours given off by the fabrics.

Clark M. Welch, a U.S. research chemist has developed a new technique that makes cotton fabrics and blends wrinkle-resistant without using formaldehyde. The process uses nontoxic polycarboxylic acids that like formaldehyde cross-link cellulose molecules in cotton to make fabrics more durable. The resultant material is 20% stronger and easier to dye and clean than the former.

Australian bird may help the deaf

A small Australian bird may change the lives of many deaf people throughout the world. The Plain Wanderer is a brown-and-white freckled bird with a small hole in its 10 mm wide head which is used as a small antenna. Its hearing is so sensitive it can pick up the direction of very low-frequency sounds. A team of researchers at the University of Queensland has developed a new hearing aid based on the bird's sound system. The hearing aid has been named, appropriately, the Aviphone.

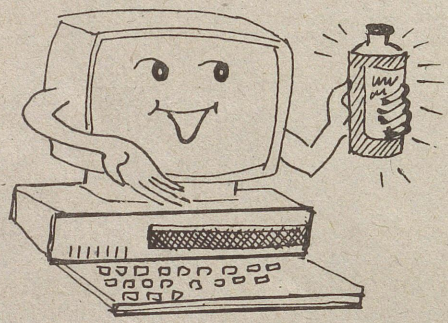
The main problem with present-day hearing aids is that they amplify all sounds, including the sound the person wishes to hear. This is where the Plain Wanderer comes in. Until recently the bird has baffled physicists with its ability to find the direction of sound waves 100 times larger than its head.

The mating call of the bird has a very long wavelength. A conventional antenna the size of its head could not pick up such long wavelengths. But the Plain Wanderer, through the small hole in its head, enables its ears to communicate physically with each other. The hole in the head produces vibrations equivalent to patterns produced by a much larger head or antenna. The Aviphone incorporates the bird's natural technology. It is worn on both ears so that the wearer can more easily select one voice from a group of speakers.

Antibodies for cancer complications

AN Australian medical research team has developed an antibody to treat and prevent a common complication of cancer—high levels of calcium. High blood calcium levels add to the suffering of many cancer patients by causing dehydration, drowsiness, mental changes and sometimes coma.

The Australian group discovered last year that certain types of cancer cells produce a hormone that affects bone and kidney function to raise calcium levels. They synthesised parts of the hormone and subsequently were able to produce antibodies that prevent high blood calcium levels. The antibodies could also be used to develop a simple blood test to detect certain cancers in their early stages.

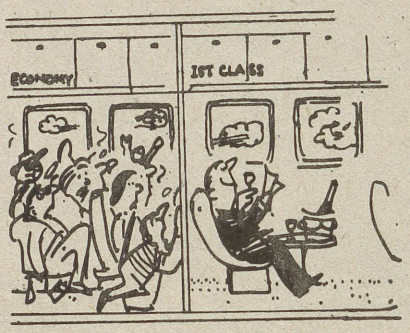


Computer to design new drugs

ACADEMICS from Manchester University in north-west England, are preparing a computer system capable of designing new life-saving drugs. The system, believed to be the first of its kind for commercial applications, uses a "supercomputer" to carry out thousands of millions of calculations a second. This removes much of the guesswork which has been part of the costly conventional development of drugs.

The academics have named the system "Prometheus" and set up a special company, Proteus Biotechnology, to exploit their work in mathematically modelling the way in which drugs interact inside the body. The complex molecules making up a drug or protein interact according to their chemical composition and their shape. Although the chemical composition of many such compounds has now been worked out, the shapes of relatively few have so far been measured.

Computer codes developed by scientists at Proteus, enable the chemists to work out the shape from the chemical composition. That will allow the creation of tailor-made drugs "on-screen", with the chemist altering the composition and shape to achieve the right level of interaction with target compounds.



Rigours of air travel

EVEN if he survives a hijack or an air crash, an economy-class passenger could still land up in hospital. In extreme cases flights as short as three hours can even lead to death. This in short is what the economy-class syndrome (ECS) is all about. Incidentally two American doctors who studied this complaint were themselves victims of ECS.

In the economy-class the distance between the edge of the seat to the one in front is usually 36 cm compared with 82 cm in first class. Economy-class seats lean back some 12 cm while first-class armchairs recline by 37 cm. Obviously the movements of the economy-class passengers are restricted. This leads to interruption in the flow of blood causing clots, which in turn cut off the supply of oxygen to various organs and kill them.

Those predisposed to coronary heart disease are more prone to the syndrome. As also those who drink a lot on their flights. Besides, older and shorter people are more likely to suffer from it. But apart from shelling out the extra amount for first class travel what do the economy class passengers do? Well, they are advised to walk about on long flights and drink plenty of soft drinks.

Sleeping position and cot deaths

MOTHERS are advised to put their babies in a supine rather than a prone position to reduce the risk of cot death. In separate studies several researchers have arrived at the conclusion that there is a higher percentage of babies found dead lying face down as compared with the normal sleeping position (*Lancet*, Sept. 24, 1988).

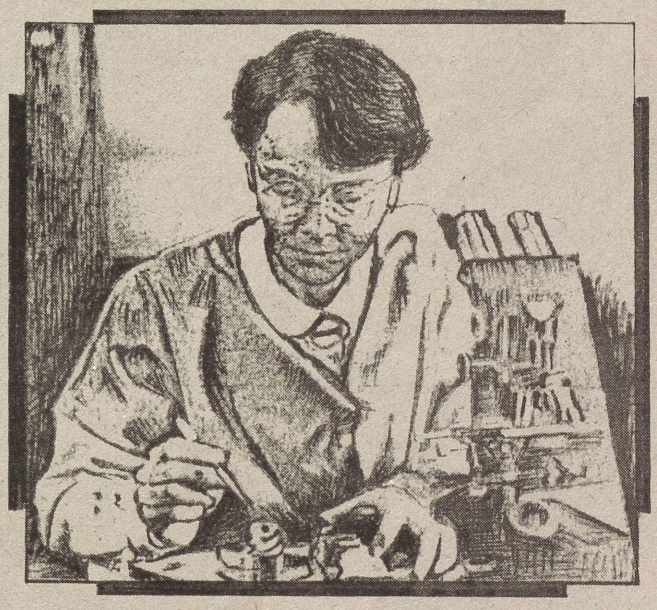
Babies with a low birth-weight are more prone to cot death. It has also been shown that some type of mattresses are much more liable to produce nasal obstruction than others. A report from the United States points to an increased prevalence of babies being found dead who are found sleeping face down on water-bed cot mattresses.

Barbara McClintock— an American karmayogi

"IF you know you're right, you don't care. You know that sooner or later, it will come out in the wash," says Barbara McClintock. These words are the epitome of her life as a scientist. After more than 30 years of her discovery of what is known as "jumping genes"—the time when she was ignored and even ridiculed—she was awarded the Nobel Prize in medicine and physiology. But she never cared for the scientific community that did not see truth when it was before its eyes. Her discovery was re-discovered despite the indifference shown towards her. Nevertheless, even today, she is an outsider in her own laboratory, her colleagues find her a difficult person, and the scientific community considers her an old fashioned scientist moulded in the tradition of the Austrian monk Gregor Mendel. Hardly a few years ago she was living in a stable, did not own a car, had no secretary, no sophisticated equipment nor a co-worker. Her life is the struggles of a single woman (she is still unmarried) against the conventions of the world and science. Even at the late age of 86 years, she lives alone—physically, emotionally and intellectually—and pursues her research interests religiously like an Indian *karmayogi.*

Born on June 16, 1902 at Hartford, Connecticut, U.S.A., Barbara has been a loner from her childhood. She needed no attention when she was in cradle. She used to remonstrate even when her mother hugged her. She loved to sit alone absorbed with herself. In course of time, she became an avid reader. She also developed the habit of thinking things on her own. At the age of five, she asked her father to bring her a set of tools. When he brought some toys, she declined to accept them and wanted real tools. Though her father was a doctor in the U.S. Army, he never discussed science with her. Nor was anybody among her two sisters and one brother interested in science. But she was given the freedom to do what she liked. She was also allowed to play games such as volleyball, ice-skating, football, baseball, etc., with boys in her locality. When her mother tried to teach her the ways of women, she rebelled against the conventions set for women. In fact, her mother was scared that one day she might become a college professor and tried her best to dissuade her from taking higher education. But at an early age Barbara had decided that she would educate herself, come what may, because she knew her father would not be in a position to finance her studies. In 1919, she joined the Cornell University College of Agriculture against her mother's wishes. She cut off her long hair and gave up wearing loose dresses because they were not convenient for working in an agricultural field. She knew there were some disadvantages in being a woman but, then, she was ready to face the consequences of her actions for the pleasure of doing what she wanted.

When Barbara was still an undergraduate student, she took up research on the hereditary mechanism of Indian corn, what is now known as "Genetics". In the congenial research atmosphere of Professor Rollins A. Emerson's laboratory at Cornell she started examining the relationship between visible characteristics of kernels of corn such as shape, size, colour variations, etc., and chromosomes—the carriers of heredity—in their cells. A chromosome is a necklace-like structure seen in the cell under a powerful microscope. It is composed of genes, the basic units of heredity, which are strung like beads in the necklace. Till then, plant breeders were crossing two types of corns and



Barbara McClintock at work at Cold Spring Harbor, New York in 1947

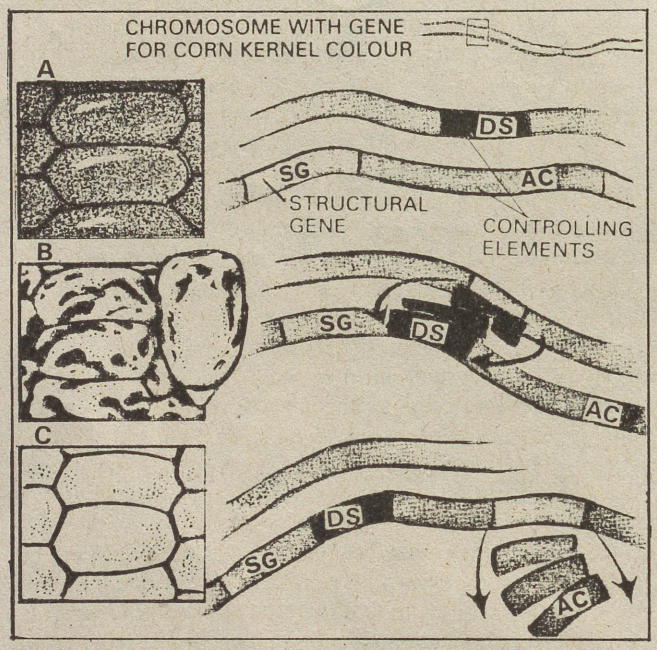
studying their progeny, while in laboratories scientists were studying chromosomes under microscopes. Barbara combined the task of both. She bred generation after generation of corns in the field and studied the changes that appeared in their chromosomes under the microscope. It was a hard life. She had to get up early in the morning, visit the field, take care that every plant was properly watered and got proper shade at noon. She also had to keep a watch for any chance pollination which might spoil her experiment. All the plants were to be properly labelled so that the changes in the characteristics of their kernels that appeared from one generation to another could be analysed and their link to the changes in the sequence of genes in the chromosomes could be identified. This work brought her

considerable respect among her fellow students and scientists. She knew research along these lines would unlock the secrets of the cell machinery. All her future research work was therefore along these lines only. Shortly, she became so adept at her work that she could predict the changes that would occur in chromosomes after studying the changes seen in the various visible characteristics of the kernels and leaves of a corn plant after a breeding experiment.

Although Barbara had earned respect as a promising young scientist, she was not sure she wanted to become one. On a fellowship she went to Germany but when she returned she had no job. In those days before the Second World War, the United States was reeling under an economic depression. There was job scarcity in all fields. At that time Barbara was thinking of changing her field of investigation to meteorology but Professor Emerson saved her for genetics. He managed to secure a two-year fellowship for her. Later, in 1936, she secured a teaching assignment at the University of Missouri, Columbia. She also continued her studies on corn genetics. However, in course of time she realised that the university authorities were not keen to promote her to the next higher grade. Her unconventional way of life and her care-two-hoot attitude to university rules and regulations had made her unpopular in the eyes of the authorities. She was victimized just because she was a woman; for the same reasons a man would not have been. For instance, once she entered her laboratory through a window because she had forgot to bring the key. Somebody took a photograph while she was climbing up the window! Against the conventions of the university, she allowed women students to stay in the laboratory after 11 P.M. Another allegation levelled against her was that she kept to herself and did not mix with her colleagues. However, it was during her stay here that she in collaboration with Harriet Creighton laid the cornerstone of research in genetics. They conclusively proved that chromosomes exchange genetic information and physical material in the early stages of cell division. This work fetched her several awards and honours in her later life when she was ridiculed for the discovery of jumping genes.

Finally, after five years at the University of Missouri, Barbara could not stand discrimination any more. She took a long leave and went to visit the Carnegie Institution of Washington's laboratory at Cold Spring Harbour, New York, on the invitation of one of her biologist friends. Here she found environment suitable to her taste. She had no teaching responsibility, no red-tape dealings, and freedom from office politics. She could devote her time exclusively to research. Moreover, woods and beaches were near the laboratory. She could pursue her hobby of walking in the woods and on beaches and watch birds, animals and marine life. After two years she became a permanent employee of the laboratory and has been there ever since. Here she continued her studies of corn genetics. One day in the winter of 1944, while walking in corn field, one thing suddenly struck her. She felt that the colour of corn kernels changed from black to speckled to white from one generation to another, as though something were controlling this characteristic of corn. She decided to investigate what it was. For the next six years she was totally devoted to this investigation. Her analysis of the results of corn breeding generation after generation forced her to arrive at a revolutionary conclusion: Genes are not simply passive carriers of hereditary characteristics from parents to offsprings. Some genes act like electric switches. They control the functioning of neighbouring genes, switching them "On" or "Off". Moreover, these "control genes" do not stay at one place on the necklace-like structure of chromosome. They jump from one place to another, bringing in unpredictable changes in the hereditary characteristics of future generations of corn.

In 1951, when Barbara presented the findings of her studies at a seminar in her own laboratory, a stony silence



This self-explanatory diagram shows gene jumping. SG is a gene that decides the colour characteristics of the kernels of corn. DS and AC are two control genes that jump. The Inset A shows the black colour of the kernels when its DS gene has not yet been switched "On". The inset B shows the control gene in the process of switching "On" DS gene. That is why the kernels are speckled. Inset C shows the kernels when the DS gene has been completely switched "On"

greeted her. In those days, chromosomes with bead-like genes were considered fixed entities, but she was talking about movable and controlling genes. She felt her colleagues were prejudiced and were taking her lightly. In the meanwhile she was elected a Fellow of the prestigious U.S. National Academy of Sciences and President of the

Genetics Society of America. So, as and when she was invited to give a lecture outside her laboratory she welcomed the opportunity to present her new findings. But, again, she met the same stony silence. It soon became obvious to her, when even invitations stopped coming, that the scientific community did not approve of her revolutionary findings. She realised she was being ridiculed for her discovery. After the initial setback, Barbara took everything into stride because she knew she was on the right track. She did not care what the scientific community or the world thought about her and her findings. She published them in the annual reports of the Carnegie Institution of Washington which hardly a few scientists read. In 1949,



A recent photo of Barbara McClintock holding samples of corn, the subject of her experiments (U.S.I.S.)

she also wrote a 90-page manuscript describing her work and results. Meanwhile, she patiently continued her work in the tradition of the Austrian monk and father of genetics, George Mendel. She withdrew from her colleagues at the laboratory and drew inspiration to pursue her work from her inner self.

Actually, Barbara was far ahead of her times but not much, unlike Gregor Mendel, who died before the world woke up to his wonderful discoveries in genetics. In the 60s, when the subject of molecular biology gathered momentum, a number of startling discoveries were made. One of the discoveries was of gene jumping observed in *E. Coli, Salmonella,* and *Drosophila.* At that time Barbara again tried to bring to the attention of the scientific community the significance of her discovery but nobody was ready to listen to her. In fact, she was considered an "old bag" and her methods of research primitive. What had happened in the meantime is that Barbara had stuck to her old ways of performing genetics experiments—the long drawn-out process of sowing corns, looking after them, labelling them and then observing their developing cells under a microsocope. The younger generation of biologists had been trained to obtain results faster through other techniques. They had therefore developed prejudice against her methods and were not ready to listen to her. Isolated from her colleagues and even the younger scientific community, with no students or assistants, she eventually decided not to talk about her work at all and even stopped publishing it. Nevertheless, she took pains to explain her results to any one who came to listen to her. But if anybody, even a Nobel Laureate, tried to convince her that she was wrong, she would become wild. Meanwhile, she was given several prestigious awards and honours for her previous contributions to genetics.

It was only in 1983 when the Nobel Prize in medicine and physiology was awarded to her for the discovery of jumping genes that her devotion and search for truth received due recognition. Perhaps, any other woman of lesser mettle would have given up her discovery and shifted to some newly emerging field of biology. Today it is believed that "control" genes that jump are present in all living beings, including humans. Obviously, these genes are responsible for causing sudden changes called "mutations" in chromosomes. Their study could throw light on how cancer cells develop, how bacteria become resistant to drugs and viruses work, among other things. Still more important is their role in the dimly understood subject of the evolution of life on earth. In fact, due to the significance of her discoveries, Barbara is today rated only next to Charles Darwin who propounded the theory of evolution of life.

Five feet tall and bright eyed, 86 year old Barbara is still fit and active in research. She works 16 hours a day and relaxes in the evening by going on long walks through woods and on beaches. She enjoys watching birds, insects, animals and marine beings. She also reads a variety of subjects. She is proud to call herself a mystic. Like her unconventional way of life, her thoughts on scientific research are also unconventional. She says, "We're trying to put limits on ourselves by following the scientific method"! One should have patience to observe what the material has to tell, she emphasises. About her own research she modestly says she had not done anything. She had simply watched corns solve the problems she posed to them ! "As you look at these things (corn plants), they become part of you," she says, "And you forget yourself. The main thing about it is you forget yourself".

Dilip M. Salwi

Trees and their importance

THE first attempt at tree rehabilitation on a national scale was made in July 1947 when a tree-planting week was celebrated in Delhi in which several Indian national leaders participated. The main objective of celebrating the tree-planting week was to focus the attention of people on the national importance of planting trees and to make them tree-conscious. The festival of trees is now a national event in which tree as a symbol of enduring peace is the central theme of celebrations. It is celebrated on a progressively bigger scale every year and is not confined to cities and towns alone; it has reached villages too. Trees now mean better crops, better living conditions, better cattle and more beautiful villages. Our country is celebrating this year the 39th Vanmahotsava festival.

In the ancient times, forests dominated civilization but now civilization dominates forests. There is hardly any commodity or activity in everyday life which is not related with some elements of forest origin. Trees help in improving the quality of life by playing a dual role of production and protection. Productivity of trees includes wood for fuel and timber, leaves for fodder, fruits for food and many items for cottage industries. Pulp, paper, ply, sports goods and match box industries are purely based on forest. The present requirement of fuel-wood in the country is about 200 million cubic meters. It is likely to rise to 225 million cubic meters by the end of the century. The time does not seem far away when the world would have sufficient food but not enough fuel to cook it. Because of the scarcity of fuel-wood most of the cow-dung is being used as a source of energy which otherwise may have been used in agricultural fields as organic manure.



Fig. 1. A man-made mixed forest at Naya Nangal

The role of timber in the construction of buildings, manufacture of railway bogies, bodies of buses and trucks, furniture items, agricultural implements, toys and other household goods is well known. The horticulture industry also cannot exist without forestry because it provides wood for packing cases. In Himachal Pradesh, shortage of packing wood is creating a serious problem for the horticulture industry and has led to the introduction of corrugated paper-packing materials.

The forests also help to generate employment. Trees generate employment through soil-working, planting, maintenance, felling and logging, etc. Some tree-based raw material industries are dairy (using leaf fodder from many tree species), silk (Mulberry), tassar (Arjun), oil-extraction (Mahua and Neem), 'Beeri' and 'Pattal' making (from leaves), tanning (Babul), resin-tapping (Chir Pine), katha (Khair), fire-boards (Pulp) and manufacture of agricultural implements, etc. All these industries provide employment to a large number of persons.

Besides being productive, trees also improve the quality of life. Trees help to stabilize and increase agricultural production which mainly depends on a balanced agro-ecosystem with trees and crops as its major components. The notion that trees are the enemies of agricultural crops is wrong. It is now widely accepted that agriculture is not independent of trees. Unplanned destruction of trees for quick monetary returns, consolidation of land holdings, industrialisation, construction of dams and roads, etc., leads to creation of desert conditions. Forests not only regulate water supply for agricultural crops but also influence rainfall, temperature, humidity, stream-flow, silting in reservoirs, water and wind erosion, soil fertility, etc. All these factors in one way or the other affect agricultural productivity. Depleting forest resources therefore weaken the agricultural base of a country. They indicate an emergent need for planned conservation of existing forests and the creation of new ones.

Tree-cover in the catchment areas prevents the erosion of sandy slopes which leads to the silting of reservoirs. Trees assist in reducing the water flow, increasing its percolation, and regulating river flow to check the flood-drought cycle. In the absence of trees, heavy rains lead to the formation of *'gullies'* in the lower hills and *'choes'* in the foot-hills. In our country, as much as 175 million hectares out of the total 329 million hectares area are exposed to environmental hazards such as soil erosion, water-logging and salinity, etc.

It is now an established fact that trees play an important role in reducing environmental pollution. Trees maintain oxygen-carbon dioxide balance in the atmosphere by absorbing carbon dioxide and releasing oxygen which is necessary for animals to breath in. On national highways, the high intensity of traffic discharges a variety of toxic gases in the atmosphere. In industrial areas, chimneys release thick smoke. Trees either absorb these gases and smoke or do not allow them to diffuse in the adjoining environment or rise up in the atmosphere. Planting of

pollution-resistant trees along the national highways and in the industrial areas will therefore be of great help to mankind.

Trees also save the human habitat from heavy duststorms, coal dust released by industrial units, and from hot and dry winds. They provide human beings shade and shelter against sun and rain. Planting trees in the form of shelter belts provides an effective measure of checking the spread of deserts. Forests also provide shelter to wild life. The depleting forests in the country have resulted in the dwindling of natural habitat for India's varied and beautiful wild life. The country has, as a result, lost a good number of its rich heritage of birds and mammals.

According to the national forest policy, 33% of the country's total geographic area of 329 million hectares should be under forests—60% of which should be in the hilly areas and the rest in the plains. At the time of the independence, India had nearly 75 million hectares (about 22%) under forest cover. Official data based on satellite survey show that the country's forest cover has now drastically been reduced to hardly 10% owing to expanding industrialisation, urbanisation, growth of population and illegal deforestation. Wastelands creation is attributed to factors like sheet erosion, waterlogging, salinity and alkalinity, wind erosion, stream erosion, shifting cultivation, sand dune movement and, not the least, deforestation.

Our country's forest assets are in different stages of degradation. There is still time to recover the lost ground. However, conservation of the existing forests and planting of new ones will not be successful unless it is made a people's movement. Involvement of people in such a movement is possible only if they are made aware of the importance of trees in their livelihood. Need of the hour is to evolve an action plan involving the public, professional and political leaders for conservation of forest eco-systems, especially in the Himalayas, the Western Ghats and the Eastern Ghats. Organised efforts like observance of the 'Vanmahotsava' festival started by the then Union Minister K.M. Munshi is early fifties, the 'Chipko Andolan' in the Garhwal Himalayas (spearheaded by its leader Sunderlal Bahuguna) and 'Appiko' movement in Karnataka can only save the land from extensive denudation and consequent destruction. These movements could become more successful by organising camps for rural masses at the village and block level where they can be imparted knowledge on the subject of Social Forestry and the role of trees in human life. Educational curriculum also needs to be modified. Not only courses in environment and forestry at school and college levels should be included but also practical training on tree-growing and their after-care. Some states like Himachal Pradesh and Haryana have already decided to introduce environment as a compulsary subject at school level.



Fig. 3. Tapping a pine tree for resin collection



Fig. 2. Timber and fuel-wood—important forest-products

S.K. Varma
Head, Botany Department
Shivalik College, Naya Nangal-140 126

Interesting properties of 65

THE number 65 is a very interesting number. It has many peculiarities and amazing characteristics. Some of its interesting properties are given below.

1. Interesting relations exist between the digits of 65, viz.,

$$6^2-5 = 6+5^2$$

2. The following operations performed on the digits of 65 yield the first digit, the square of the first digit, and its cubic power respectively,

$$_{\Sigma}6-_{\Sigma}5 = 6$$
$$_{\Sigma}6+_{\Sigma}5 = 6^2$$
$$(_{\Sigma}6)^2-(_{\Sigma}5)^2 = 6^3$$

Also, the following operation produces a monodigital palindrome with 6 as the repeating digit:

$$(_{\Sigma}6)^2 + (_{\Sigma}5)^2 = 666$$

3. Subtracting the square of 65 from the square of its reversal leads to 1089, a very interesting number:

$$65^2-56^2 = 1089$$

4. Replacing the first digit of 65 by its upside-down digit produces the number 95. The original number 65 can be derived from this number on carrying out some simple operations. Taking the sum and the difference of the digits of 95 and multiplying the resulting numbers and then reversing the product generates 65:

$$9+5 = 14$$
$$9-5 = 4$$
$$14\times4 = 56$$

Reversal of 56 = 65

5. Many squares can be derived from the number 65. After squaring and adding the digits of 65, the reversal of the resulting number produces a square,

$$6^2+5^2=61$$

Reversal of $61=16=4^2$

Joining the number 61 to the right of the number 65 generates a square,

$$6561=81^2$$

Subtracting 61 from the number 65 again results in a square,

$$65-61=4=2^2$$

Adding the factors of 65 and reversing the resulting number also produces a square,

$$5+13=18$$

Reversal of $18=81=9^2$

Multiplying the digits of 65 and adding the product to the first digit of 65 leads to a square

$$6\times5+6=36=6^2$$

A square also results on carrying out the following operations which are self-explanatory:

$$6^3-5^3=91$$
$$5^3-6^2=89$$
$$91-89 = \boxed{2}$$
$$6\boxed{2}5 = 25$$

On squaring the number 65 one obtains,

$$65^2=4225$$

The resulting number 4225 produces many squares. The sum of the squares of the digits of this number yields a square,

$$4^2+2^2+2^2+5^2=49=7^2$$

The first digit of 4225 is a square. The sum of the second and the third digits is a square, and so also is the sum of the first and the last digits and the sum of the last three digits of the number 4225. Separating the number 4225 into two-digit blocks, the number block on the right, that is, 25 is a square.

6. A cubic number is also generated from 65 after performing the following operations:

$$5^3-6^2 = \underline{8}\,\underline{9}$$
$$6\underline{8}\underline{9} = 19^3$$

7. The number 65 may be expressed as the difference of two squares in two different ways:

$$65=33^2-32^2=9^2-4^2$$

The square of 65 is also expressible as the difference of two squares in four distinct ways, viz.,

$$65^2=97^2-72^2$$
$$=169^2-156^2$$
$$=425^2-420^2$$
$$=2113^2-2112^2$$

8. The number 65 may be expressed as the sum of two cubes, e.g.,

$$65=1^3+4^3$$

Its reversal 56 is also expressible as the sum of two fractional cubes:

$$56=\left(\frac{10}{3}\right)^3+\left(\frac{8}{3}\right)^3$$

9. The number 65 has close mathematical links with many triangular numbers [1,3,6,10,15,21,.....where n^{th} term = $n(n+1)/2$]. The first digit (6) and also its square (36) are both triangular. The number 65 is itself the sum of two triangular numbers

$$65 = 55 + 10$$

It is also expressible as the difference of two triangular numbers in two different ways:

$$65=66-1 =120-55$$

Multiplying the sum of the digits of 65 with the first or the second digit yields triangular numbers:

$$(6+5)\times5=55$$
$$(6+5)\times6=66$$

Triangular numbers are also obtained as follows:

$$_{\Sigma}6-_{\Sigma}5 = 6$$
$$_{\Sigma}6+_{\Sigma}5 = 36$$
$$(_{\Sigma}6)^2 + (_{\Sigma}5)^2 = 666$$
$$6^3-5^3 = 91$$

Adding 65 to one of its factors, 13, generates a triangular number:

$$65+13= 78$$

Multiplying the upside-down digit of 6, i.e., 9 with the second digit of 65 generates a triangular number,

$$9\times5=45$$

Subtracting the difference between the factors of 65 from the square of its first digit also leads to a triangular number:

$6^2 - (13-5) = 6^2-8 = 28$

A triangular number is also obtained when the number 65 is sandwiched between the digits of 13, one of the factors of 65,1653

A triangular number can also be obtained from the square of 65, viz., 4225 by performing certain operations. The number 4225 may be separated into two-digit blocks in two different ways, namely, 42, 25; and 45, 22. By taking the respective products of these number blocks, one obtains

$42\times25=1050$
$45\times22= 990$

Of these, the latter number, namely, 990 is triangular while from 1050 triangular numbers can be generated on carrying out the following operations:

$\Sigma 5 = 15$
$6^2-5=5^2+6=31$
$1050-15=1035 \rightarrow$Triangular number
$1050+31=1081 \rightarrow$Triangular number

10. Many palindromes (i.e., numbers which read the same forward as well as backward) can be obtained from 65. The sum of the digits of 65 is a palindrome,

$6+5=11$

Adding 65 to its reverse also generates a palindrome,

$65+56=121$

Palindromes also result in the following manner;

$6^3-5^2=191$
$5^3+6=131$
$5^3+6^2=161$
$65-\Sigma 6=44$
$(\Sigma 6)^2+(\Sigma 5)^2=666$
$5^4 + (6+5)=625+11 =636$

11. Fibonacci numbers (0,1,1,2,3,5,8,.....where $(n+2)^{nd}$ term=sum of n^{th} term and $(n+1)^{th}$ term) can also be obtained from 65. Squaring 65 and separating the resulting number into two-digit blocks and then adding these number blocks, 67 is generated,

$65^2=4225$
$42+25=67$

When this number is joined to the left of 65, a Fibonacci number is produced:

$6765 \rightarrow$ Fibonacci number

A Fibonacci number is also produced by performing the following operations on the digits of 65:

$5^3-6^2=89$

Further, it is interesting to note that the number 65 can be expressed as the difference of a Fibonacci and a palindromic number, namely,

$65 = 610 - 545$
Fibonacci number; Palindromic number

The square of 65 may be expressed as the sum of a Fibonacci and a palindromic number,

$65^2=4181+44$

12. Demlo numbers (see *S.R.*, June, 1979, p. 422) are also generated on multiplying 65 by 111 and 1111:

$65\times111=07215$; $07+15=22$
$65\times1111=072215$; $07+15=22$

Demlo numbers are also generated when 65 is multiplied by 999 and 9999:

$65\times999=64935$; $64+35=99$
$65\times9999=649935$; $64+35=99$

13. The cube of the first digit of 65 can be expressed as the sum of the cubes of three consecutive numbers, e.g.:

$6^3=3^3+4^3+5^3$

Also, the sixth power of the first digit can be expressed as the sum of three cubes in two different ways:

$6^6=4^3+24^3+32^3$
$=18^3+24^3+30^3$

The sixth power of the second digit, however, can be so expressed in only one way:

$5^6=4^3+17^3+22^3$

The cube of the sum of the factors of 65 can also be expressed as the sum of three cubes in two different ways,

$(5+13)^3=18^3=2^3+12^3+16^3$
$=9^3+12^3+15^3$

Subtracting 5, one of the factors of 65, from the parent number yields:

$65-5=60$

The cube of this number is expressible as the sum of three cubes in two different ways:

$60^3=21^3+42^3+51^3$
$=30^3+40^3+50^3$

Similarly, the cubes of the numbers obtained respectively by adding to 65 its factors 5 and 13 can be expressed as the sum of three cubes:

$(65+5)^3=70^3=7^3+54^3+57^3$
$(65+13)^3=78^3=39^3+52^3+65^3$

The cube of the product of the digits of 65 can also be expressed as the sum of three cubes, e.g.,

$(6\times5)^3=30^3=15^3+20^3+25^3$

The cubes of the following numbers deducible from the digits of 65 by performing certain operations can be expressed as the sum of three cubes:

$(6^2+5)^3=41^3=2^3+17^3+40^3$
$=6^3+32^3+33^2$
$(5^2-6)^3=19^3=3^3+10^3+18^3$
$(5^3-6^2)^3=89^3=17^3+40^3+86^3$
$(6^3-5^2)^3=191^3=39^3+146^3+156^3$

On carrying cut the following operations the factors of 65 produce the numbers 76 and 106 respectively:

$\Sigma 13-\Sigma 5= 76$
$\Sigma 13+\Sigma 5=106$

The cubes of these numbers can be expressed as the sum of three cubes in two ways and one way respectively:

$76^3=12^3+40^3+72^3$
$=31^3+33^3+72^3$
$106^3=58^3+68^3+88^3$

P.K. Mukherjee
Physics Department
Deshbandhu College
Kalkaji, New Delhi-110019

INSA Awards for young scientists

FOURTEEN brilliant scientists representing disciplines of science, engineering and technology were awarded the Indian National Science Academy Medal for Young Scientists for the year 1988. The awardees received a cash award of Rs 5000/- and a medal. The awards were presented by Dr A.S. Paintal, President of INSA and Director General ICMR, on the occasion of the 54th Annual General Meeting of INSA held on 5th October 1988 at the premises of the Academy in New Delhi.

In his presidential address Dr. Paintal called for a stop to the practice of assessing scientists on the basis of number of publications rather than their actual contributions. This policy had bred mediocrity among Indian scientists, who react by adopting easy methods for multiplying their papers, not verifying results and sending half-baked material for publication. As a result no new information was generated, he said.

Dr. Paintal was equally critical of easily funded research. He said, "Contributions by scientists who depend on their grants for their personal salaries or emoluments are not highly dependable. These people find it profitable to divide up a piece of work into several papers, and they are less inhibited when it comes to misconduct in scientific research such as plagiarism and doctoring the data".

Dr. C. Gopalan, President, Nutrition Foundation of India delivered the Sir C.V. Raman Medal lecture 1988. He spoke on practical leads that have been generated from scientific research in the field of human nutrition in India. He, however, expressed concern at the fact that the leads had not always been put to optimal use.

Dr. Gopalan cited instances when nutritional research in India had helped place several nutritional problems in their proper perspective. For instance, in the sixties it was widely propagated that Asians were lactose intolerant and so would have difficulty in digesting milk. However, studies in India showed that lactose intolerance need not necessarily imply milk intolerance. And so, Indians need not be helped with imported lactose tablets to digest milk.

Similarly the clear demonstration that the primary dietary deficiencey was not that of protein, as was being widely claimed, but that of calories has been a major contribution of Indian nutrition research. The result of this finding has been the recognition that the solution of this widespread problem does not need to depend on imports and use of expensive protein-rich concentrates, but can be achieved through the judicious use of inexpensive locally available cereal-legume traditional foods within the physical and economic reach of most poor families in the country.

After the oration Dr. Gopalan received the Sir *C.V. Raman Gold Medal* from Dr. A.S. Paintal. It is the most prestigeous award of INSA for outstanding contribution to science.

Later Dr. A.S. Paintal presented he INSA Medal for Young Scientists for the year 1988. The fourteen recipients are-

1. Dr. V.K. Arora, Department of Soils, Punjab Agricultural University, for developing and testing a model for predicting water use and irrigation scheduling in wheat.
2. Dr. M.M. Chaturvedi, Department of Zoology, Banaras Hindu University for his studies on conformational and functional changes during ageing.
3. Dr A. Jayaraman, Physical Research Laboratory for his outstanding contributions on the role of aerosols in the troposphere and the stratosphere.
4. Shri S.K. Mahata, Department of Zoology, University of Calcutta for his work on neural and/or hormonal regulation in catecholamine synthesis, release and resynthesis in avian adrenal medulla.
5. Dr K. Majumdar, UNIDO, ICGEB, New Delhi for his contributions to the synthesis and purification of oligonucleotides.
6. Dr. C.M. Nautiyal, Radiometric Dating Laboratory, Birbal Sahni Institute of Palaeobotany, Lucknow for his outstanding contributions in the field of isotope-based astrophysics and on the evolution of the early solar system.
7. Dr. Rahul Pandit, Department of Physics, Indian Institute of Science, Bangalore for his outstanding contributions to the theory of hysteresis, in particular the shapes and areas of hysteresis loops in model spin systems and the modelling of micro-emulsions.
8. Dr. M. Durga Prasad, School of Chemistry, University of Hyderabad, for his contributions to theoretical chemistry.
9. Dr. A.G. Samuelson, Department of Inorganic and Physical Chemistry, Indian Institute of Science, Bangalore for his contributions in the use of copper compounds in organic synthesis.
10. Dr. Utpal Sarkar, Theoretical Physics Area, Physical Research Laboratory, Ahmedabad for his outstanding contributions in high energy physics, in particular in the field of super-string phenomenology and on the problem of fermion masses.
11. Dr. Eklabya Sharma, Centre of Advanced Study in Botany, Banaras Hindu University for his original and outstanding work on nitrogen fixation, production, and energy conserving efficiencies of Himalayan alder plantations.
12. Dr. Y.N. Srikant, Department of Computer Science and Automation, Indian Institute of Science, Bangalore for developing efficient algorithms for incremental parsing, semantic analysis and code generation and parallel processing compiler construction.
13. Dr. Sandhya S. Visweswariah, Astra Research Centre India, Bangalore for her outstanding contribution on immunology and study of riboflavin carrier proteins in relation to reproduction.
14. Dr. Zora Singh, Department of Horticulture, Punjab Agricultural University, Ludhiana for his studies on the elucidation of the nature and control of malformation in mango.

Hasan Jawaid Khan

Facts about premenstrual tension syndrome

MENSTRUATION is a natural phenomenon occurring regularly in all healthy reproductively viable women. Menstrual endocrinology is well understood. However, there exists a great deal of controversy about the nature and prevalence of a well-definable and variedly discomforting period immediately before the onset of menstruation. Because of its physiological and symptomatic complexity, the condition is clinically described as Pre-menstruation Tension Syndrome (PMTS or PMS). In some women, a few days immediately before the onset of menstruation are highly uncomfortable with physiological manifestations, at times so severe that medical help is needed. On the other extreme, there are women who do not even notice any abnormality and for them these days pass off without any discomfort. There are reports that some women during this period experience heightened sexual urge and maximal physical efficiency.

The human menstrual cycle is essentially a 28-day cycle in which actual menstruation occurs for about 4 days. This follows a period in which the lining of the uterus is regenerated and the ovarian follicle matures (to be ready to release an egg). This is commonly called a recovery or preovulatory period which lasts until around the middle of the menstrual cycle. Ovulation or release of the egg from the ovary usually occurs approximately between the thirteenth and fifteenth days of the 28-day cycle. The ruptured follicle, after the release of the egg, is reduced to a yellowish cellular mass—the corpus luteum of the ovary. The lining of the uterus during this period becomes soft, thick and ready to receive and implant the ovum, if fertilized. If the ovum is not fertilized, the uterus sheds the soft and thick uterine lining that leads to menstrual bleeding. The latter part of the period between ovluation and menstruation is called the premenstrual period. Towards the fag end of the premenstrual period, i.e., 3-4 days before the onset of menstruation, some women experience a period of disturbing anxieties and varied discomforts which in certain cases get exceedingly intense and almost unbearable immediately before menstrual flow starts. The tension and other physiological as well as psychological manifestations which mark this period subside gradually after the start of the menstrual flow.

Despite the widespread occurrence of this phenomenon, our understanding of PMTS is frustratingly meagre. Investigators are not unanimous even with respect to the essential symptoms and their severity which characterize PMTS. It is not known why only a certain percentage of women suffer from PMTS and not all. A convincing explanation still evades us. The physical changes and emotional upheavals associated with PMTS in sizable percentage of women are so wide and varied, and above all, patient-specific, that they compel us to doubt the uniformity of PMTS in all women. Perhaps the threshold of discomfort tolerance determines whether the premenstrual days will pass off calmly or whether this period will be noticeable.

It is well-known that menstruation characteristics to a great extent are inherited by daughters from their mothers, but many a time daughters unconsciously tend to mimic their mother's reactions or responses during menses and perhaps of the pre-menstrual days too. It is desirable, therefore, for the mothers to minimize to the extent possible the exhibition of discomfort of these days.

Even though PMTS is not considered clinically a disease yet, at times, its manifestations are rather severe warranting clinical intervention. PMTS commonly manifests as a combination of symptoms including personality changes, presence of depression or anxiety, fatigue, irritability, emotional instability, often accompanied by frequent episodes of crying. Other physical manifestations include backache, severe abdominal cramps, headaches, overall swelling of the body—more pronounced in the abdomen, legs, anklets and the breasts in particular. An increased tendency of attacks of migraine has been reported in those suffering from PMTS. Noticeable gain in weight is a symptom which is shared by all women irrespective of whether they have definable PMTS or otherwise.

PMTS edema is more easily felt in the breast. Breast size, specially in young girls or in women who have not yet breast-fed babies, undergo significant fluctuations during different phases of menstrual cycle. Immediately before menstruation, the breast engorgement is maximum; sometimes the increase in volume approaches 25% of the original size . The breasts also get somewhat tender, more dense, even painful and in certain cases may exhibit nodularity (knotty feelings) too. The breast engorgement is attributed to increased blood flow as well as elevated water and salt retention in the area. Breast engorgement of the PMTS days gradually decreases with age and touches the lowest in the middle of a woman's menstrual life. After that it again increases especially in the forties and becomes severe again before menopause whereafter it disappears. No special treatment is needed to manage breast engorgement or associated discomforts. It may, however, be mentioned that breast examination for the detection of breast nodules is not recommended during days of PMTS engorgement which normally accompanies nodularity of breasts, because it is likely to be mistaken for growing tumors. A week after the start of menstruation, when the size of the breast is minimum, is ideal for breast examination.

An interesting survey involving over 10,000 women in USA was undertaken some time back. The women were given a questionnaire and asked whether they experienced

any of the listed symptoms/discomforts prior to menstruation. Though minor discomforts directly related with the overall edema prior to the onset of menses was experienced by all, a significant percentage of women also reported noticeable degree of depression or anxiety, fatigue and irritability. Despite variability, about 25%-30% women reported only one of the listed symptoms. Only a small percentage reported combinations of two or more pre-menstrual tension symptoms which were moderate. Only 5% of the total women surveyed, extrapolating from those who reported multiple or severe symptoms, warranted clinical involvement or management for the alleviation of their pre-menstrual discomforts. It was also revealed in this survey that many women tend to exaggerate their premenstrual discomforts and that in many cases the discomfort is psychological or habitual rather than real.

Etiology

PMTS is related by physiologists to the heavy hormonal changes during pre-menstrual days, although views on the specific hormones producing PMTS are highly divergent. Many hold the changing profiles of estrogen and progesterone during pre-menstrual period as the root cause of PMTS. It is believed that diminished progesterone, either absolutely or in relation to estrogen levels, is responsible for PMTS. It is known that corpus luteum regresses and stops secreting progesterone at this time—the level of which, therefore, falls. Similarly the estrogen level too is low during PMTS days since Graafian follicles are stimulated to develop actively only after onset of menstruation. Role of estrogen in building up pre-menstrual tension, as is held by some authors, seems uncertain because tension develops late in the cycle and not at the time of ovulation when estrogen secretion is at its peak. According to some physiologists, increased vasopressin (antidiuretic hormone of posterior pituitary) secretion seems to contribute significantly to the pre-menstrual fluid retention which in turn leads to certain discomforts. Similarly, other theories postulating pre-menstrual hypoglycemia (a state of abnormally low concentration of glucose in the circulating blood), or release of a specific menstrual toxin responsible for PMTS are also not yet substantiated. Recently hyperprolactinemia (an abnormally large concentration of prolactin in plasma) has been suggested as a cause for PMTS. Women with PMTS symptoms when treated with bromocriptine (an active dopamine agonist) experienced significant improvement in breast engorgement and recorded reduction in body weight and even elevation in mood compared with controls (women who do not apparently experience discomforting PMTS). However, in another clinical trial, efficacy of bromocriptine for the management of PMTS could not be substantiated.

Relief

For routine management of PMTS discomforts, the following recommendations deserve consideration.

(1) A tablet or two of aspirin or other analgesics relieve the PMTS discomfort to a large extent.

(2) Restriction of salt intake prior to menstruation is helpful in containing edema and hence weight gain which appear to be associated with many premenstrual discomforts. Further relief is possible if diuretics are given to increase urine output along with restricted salt intake to achieve reduction of tissue fluid. Diuretics normally are not administered unless PMTS discomforts are severe.

(3) Appropriate hormone supplementation is sometimes recommended. Normally traces of both male and female hormones are exogenously administered to provide temporary comfort. This should, however, be done under medical advice.

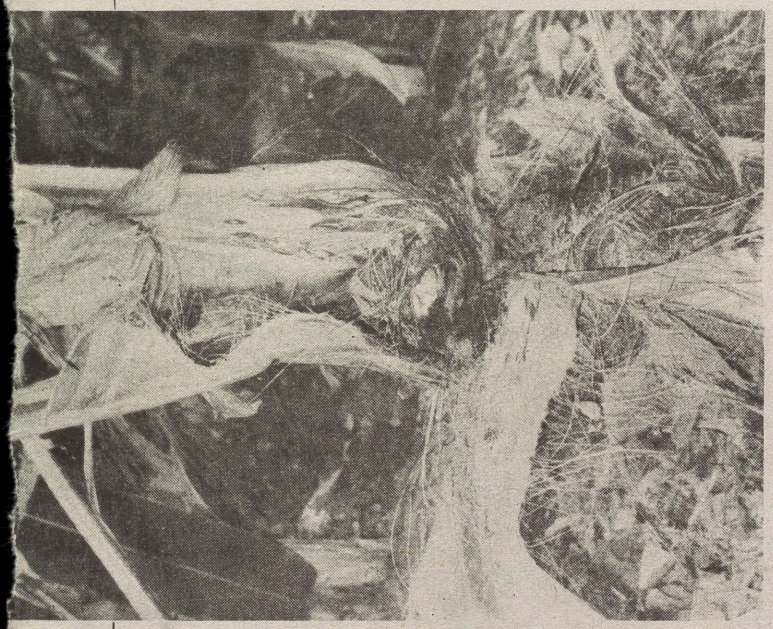
Jyotika Kanwar
Christian Medical College
Ludhiana
K.C. Kanwar
Biophysics Department
Panjab University
Chandigarh

Improved red palm weevil detector

THE coconut palm has a dreaded pest called the Red Palm Weevil, *Rhynchophorus ferrugineus* F. A severe infestation of the weevils can even kill the palms. In fact, this accounts for considerable losses in palm growing areas. The nature of its infestation being internal the weevil remains unnoticed till a very late stage.

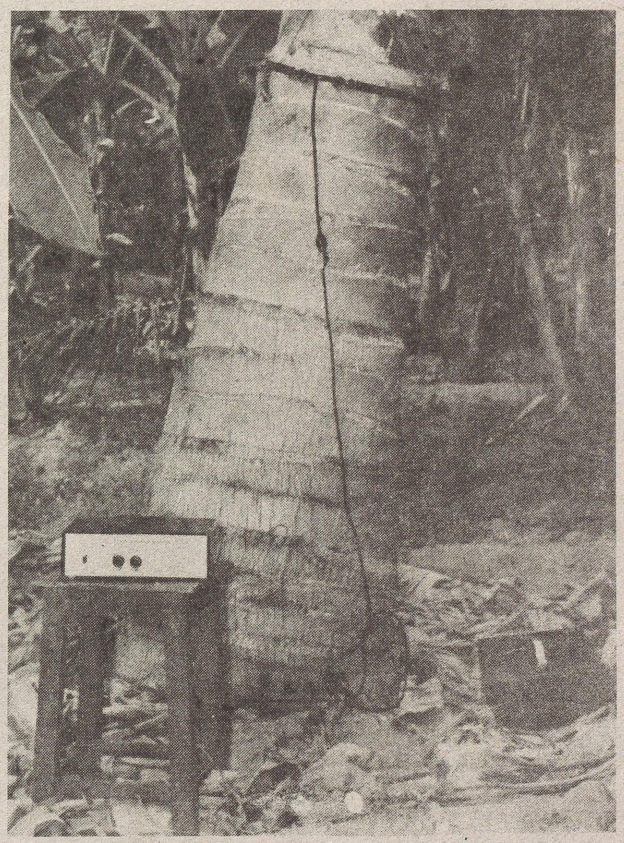
Young coconut palms are particularly susceptible to the infestation. The adult female weevil bores its way to the tissues inside young coconut palms, where it lays eggs. After an incubation period of 2 to 3 days the eggs hatch. The just hatched grubs tunnel into the palm trunk by chewing the live tissues and feed on sap.

Since the grubs feed internally they remain unnoticed till a very late stage. Only when symptoms like oozing out of a brown fluid from the exit holes, drooping of leaves, etc. appear that the infestation is noticed. But by this time it is already too late, the growing portion of the palm is affected and the palm succumbs to the pest infestation.



A severe infestation of the weevil seriously damages the internal tissues of a young coconut palm

An electronic amplifier developed by T.A. Davis in 1964 has been used to detect the presence of the insects. But in field tests it was found to be not so effective as its signal output was corrupted by all extraneous noises. A much improved Red Palm Weevil Detector has been developed at the College of Engineering, Trivandrum and tested at the CPCRI Regional Station in Kerala. The instrument detects only the feeding sound of the grubs, eliminating all the unwanted signals.



The instrument mounted on a suitable position on the stem of the coconut palm

It is mounted on a suitable position on the stem of the coconut palm and the feeding sound is watched for. In infested palm trees a clear feeding sound can be heard on the speaker. Once an infestation is noticed at an early stage, application of effective insecticides can save the infested palm. Curative measures are ineffective at a later stage.

In field tests the instrument showed good results. Of a total of 1952 palms tested at six locations 47 palms showed positive indications of weevil infestation. Only 16 of them showed external symptoms.

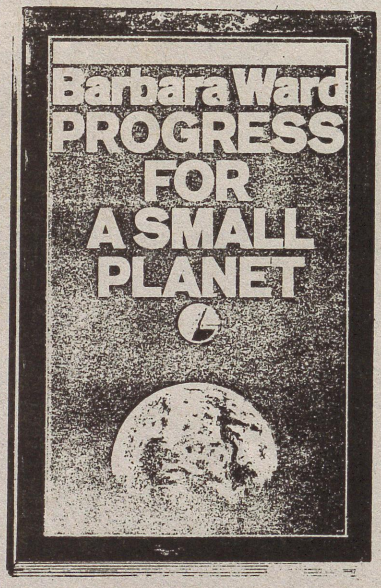
Periodical checking of young palms with the equipment and prompt treatment can save the affected palms. The instrument is likely to cost Rs. 3,000/-

Hasan Jawaid Khan

BOOK REVIEWS

PROGRESS FOR A SMALL PLANET *by* Barbara Ward, *Earthscan Publications Limited,* 3, Endsleigh Street, London WC 1 H ODD, U.K:, Pp. 290, £ 5.95

WE are not living in the Modern Age. We are living in the Age of Contradictions. Have a look around yourself. You will observe contradictions in almost every aspect of your life. Tall skyscrapers stand next to primitive huts of slum-dwellers! Food is wasted in marriage parties and hotels, while to secure two square meals a day is a Herculean task in interior villages! You can talk with a person across seas and oceans via satellites but cannot do so with someone living on the outskirts of your city! Hue and cry against air pollution is raised, while the number of vehicles on the roads is increasing exponentially! Indeed, such contradictions boggle the mind of any thinking individual and he or she wonders what the world is coming to. Will these contadictions end at any time in future? Or, will they be whipped up further till the doomsday arrives? One does not know



Certainly, these are troubled times which would set the stage for the new age likely to dawn upon earth, when man would live in peace free from environmental pollution or nuclear weapons. Some sociologists claim that before any new structure is built up in a society there is likely to be chaos. Perhaps, we are in that chaotic stage of evolution of the human society. At present, we have developed enough technology to meet all our needs but we have not accordingly brought in changes at the social, political and economic levels to absorb the technology without harming the environment. The book under review, an old classic recently reprinted, is aimed at exposing the common man and all types of specialists to those various levels that need to be rectified if we have to live in harmony with the environment. After all, the earth is a small planet with finite resources. We should know, if we want to survive, how to utilise the resources properly and optimally.

The book gives an idea of how the present age of contradictions or chaos was created especially in Europe and some developing countries like India, thanks to the industrial development, the formation of cities and harnessing of energy sources such as nuclear power. How these various things led to the formation of city-states with the power to govern restricted to the hands of a few privilaged. The book then goes over to the development of less developed regions because in due course it was realised that the proper development of city-states was dependent upon the less developed regions. In fact, the rising tide of masses from interior, less developed regions to the cities has put tremendous pressure on their management and resources. Efforts have begun to develop villages and town so that their problems are solved there and then. Various new unconventional energy sources and appropriate technologies are tapped and plugged into the infrastructure available in the less developed regions. Finally, the book tackles the various issues presently confronting mankind. There is a need to develop technologies not only to control wastes and pollution but also to recycle wastes and pollutants into valuable products.

The author, one of the pioneers of the development movement in the world, also gives in the book some solutions to tackle the problems created by the unchecked development in the cities. But one thing becomes very clear after reading the book: that changes need to be brought in at all social, economic and political levels of the mankind. This sounds a bit difficult now in view of human psychology, vested interests developed in the present social, economic and political structures and the money-culture that has come into circulation, everywhere in the world. The book would be of interest to social scientists, planners, policy-makers or anybody genuinely concerned about the progress of our small planet.

Dilip M. Salwi

SCIENCE TECHNOLOGY AND RURAL DEVELOPMENT Edited *by* P.L. Lamba and S.S. Solanki, *Anmol Publications,* 4378/48 Ansari Road, Darya Ganj, New Delhi-110002, pp. 297, Rs. 250.00

DEVELOPMENT, as quite a few of us perceive, involves urbanization and industrialization. Merely setting up industries and urbanizing rural areas are thought to be the best ways to remove all ills that beset an under-developed society. However, little do we realize that industrialization

with very little emphasis on rural development can only succeed in creating massive unemployment and concomitant grinding poverty among the bulk of the population. Increasing levels of pollution, gas leaks, etc. are some other aspects of industrialization.

At the same time, urbanization of rural areas through acquisition of agricultural land has created serious imbalances in the social and economic spheres. Gradual decline of rural crafts, cottage and agro-based industries and depletion of green cover and the attendant environmental problems are only a few adverse consequences of this policy. Besides, the land which gives income flow in terms of agricultural output every year, after acquisition gets changed to real estate and ceases to generate income flow.

What about the poor farmer whose land has been taken away for a paltry sum of money? Divested of his ancestral profession and lacking in any other skill he heads for the city in search of employment. For him it is a choice between survival and starvation. In fact, every year an estimated 5 million people migrate to towns and cities. The result has been a four-fold increase in the country's urban population over the last few decades.

In Delhi alone about 3 lakh people move in every year. The urban population which was about 11 lakh at the time of independence has risen to about 80 lakh at present. The results are there for all to see. Some areas have the highest pollution level in the world. Civic services are going bust. Overcrowded buses, chaotic roads, lengthening queues, clogged drain pipes and uncleared garbage are all ominous portents for the future of Delhi. The recent cholera epidemic that swept parts of Delhi is a case in point.

All this calls for developments in the rural areas. Make the villages safe and more secure for the villagers and the cities would be saved further damage. In this regard the scientific community can play a major role. It has to ensure that science and technology is geared to the tackling of problems encountered in the rural environment, increasing gainful employment, reducing drudgery, increasing efficiency and productivity and inculcating the scientific temper.

Although several sporadic studies have attempted to throw light on this gigantic problem, no organized attempt has been made to find solutions. In December last year a symposium on "Science Technology and Rural Development in the Union Territory of Delhi" was perhaps the first attempt to discuss the numerous problems specific to the rural areas. Although deliberations of the symposium were confined to rural areas around Delhi, they are of as much relevance to other metropolitan areas. The recommendations emanating from the deliberations at the symposium have been brought out in the form of the volume under review.

It is an excellent volume containing twenty nine papers by leading authorities on different aspects of urbanization and industrialization. The broad areas covered in the book are: (1) Land acquisition, (2) Employment generation in rural Delhi, (3) Industrialization in rural Delhi, (4) Science, Technology and rural Delhi, (5) Transformation of the agricultural base in rural Dehi, (6) Energy in rural Delhi, (7) Education and women in rural Delhi, and (8) Rural Delhi around 2001 AD.

Researchers in the area of rural development are bound to find this book extremely useful as it contains some incisive analysis of problems in this area. The book contains a wealth of data and information on different aspects of rural Delhi. Even policy makers and planners would do well to go through this book before embarking on new projects.

Hasan Jawaid Khan

INTERFERONS—Their Impact In Biology And Medicine, Edited *by* Joyce Taylor—Papadimitriou, *Oxford University Press,* 2/10, Ansari Road, N.Delhi—110002, pp. 148, $ 20.

DISEASE and death have engaged the attention of man from very early times. The roots and traditions of medicine go back thousands of years. The history of medicine is the story of men with questioning minds at work on problems that affect the lives and health of all people. It is an exciting story interwoven with anatomy, physiology, chemistry, bacteriology, virology and immunology. We now have a wide range of cytotoxic drugs for use in generalized disease. Recently, a different type of anti-cancer drug, 'Interferons', has caught the imagination of the press, public and the medical world.

Interferon (the class of immune regulators or lymphokines) are proteins that regulate the response of cells to virus infection and cancer proliferation. The existence of such substances was first inferred from the medical observation that patients already suffering from one viral disease do not simultaneously contract a second viral disease, suggesting that the first viral infection interferes with the development of second. These extraordinarily potent substances are the subject of the most widely publicized applications of Recombinant DNA technology to date. Until recently, the study of interferons was limited by its availability in extremely small amounts. Now, however, recombinant DNA technology allows production of large quantities of interferon-like proteins for testing as a pharmaceutical product. Interferon might even be used to treat some kinds of human cancer, which have long been suspected to be caused by viruses. Perhaps the most enlightening results coming from interferon research concern cellular function during immune responses. They may prove extremely valuable in medicine. Better understanding of immune mechanisms, for example, may provide insights into the etiology of diseases such as Acquired Immune-Deficiency Syndrome (AIDS).

The book under review is divided into seven chapters and

deals with the recent developments in the interferon field. It lays stress on those interfaces which are growth areas both in interferon research and in biology and medicine. The first chapter gives a brief introduction of the genes of the interferon system. Next four chapters concentrate on the regulatory role of interferons in human immune response, cell growth and differentiation. The last two chapters cover observations which are relevant to the successful use of interferons in medicine.

The book is useful not only to interferon specialists but also to research scientists and clinicians who may want to conduct investigations in these fields. The editor has rightly admitted at the end that fascinating developments may well lie ahead for biological anti-tumor agents like interferons, whose mechanism of action is very different from that of conventional drugs.

Vijay Kaushik

INTRODUCTORY HISTOLOGY *by* R.K. Gauba, *Tata McGraw-Hill Publishing Company Ltd.*, 12/4 Asaf Ali Road, 3rd Floor, New Delhi-110002, pp 372, Price not stated.

THE book under review has twenty one chapters which are grouped under three sections. The introductory chapter is devoted to histochemical techniques and various types of microscopy and its applications to the study of cytology. Emphasis is on light and electron microscopy. The first section, a bird's eye-view of the subject, deals with various cell inclusions and their structure and function, and cell division. Section two deals with the origin, composition and characteristics of basic tissues, while the third section is devoted to the organ systems and, like any text-book on histology, deals with digestive, respiratory, excretory, reproductive systems, etc. The text material is well supplemented with many diagrams—mostly line drawings which are clear and self explanatory. However, at some places, they are unnecessarily large or redundant.

Some of the chapters definitely needed some photo-micrographs to support the text. The mention of figures in the running text could have been more liberal. A text-book of this size tends to have some inadvertant skip-offs/over-emphasis. To cite an example the section on autoradiography deserved a little better treatment. These niggles and minor over-sights apart, the book is well written. The language is lucid and easy to comprehend. The book would appeal as a text to undergraduate students and a source book to teachers.

A glossary as a ready reckoner at the end of the book would have been of further assistance to students and not the least to teachers.

K.D.P. Rao

COLOUR TELEVISION—Principles and Practice *by* R.R. Gulati, *Wiley Eastern Ltd.* 4835/24, Ansari Road, Daryaganj, New Delhi-110002, Pp. 535, Rs. 70.00

WITH the advance made in black-and-white television technology, need was felt for the introduction of colour television. However, adding colour to TV picture has proved a formidable task. So, tackling the fundamental problems of colour TV has taken considerable time. But now that the major problems are solved, colour TV technology is advancing fast and it is a safe guess that colour TV will become the leading form of telecasting in the world before long. Besides broadcasting, colour TV finds important applications in education, space exploration, industry, medicine, and research.

The book under review is a comprehensive text on modern colour TV with special emphasis on PAL colour system which is adopted by India, U.K. and many other countries. Two other colour systems currently in use in the world are NTSC and SECAM. The former system is in use in the U.S.A., Japan and many other countries while the latter is adopted by France, Russia and many East-European countries. A brief discussion about these colour systems appears in Chapter 6. Chapters 1 to 5 are devoted to colour TV optics, colour signal generation, modulation and transmission. Chapter 7 deals with PAL colour receivers while Chapter 8 discusses colour TV standards and modern receiver perspective. Chapters 9 to 14 give details of different subsystems, including vision, IF subsystem, the FM sound subsystem and the chroma processing subsystem.

Details about vertical scanning circuits are covered in Chapter 15 while line scan and high voltage generation circuits are dealt with in Chapter 16. Chapter 17 explains switched mode power supply (SMPS) technology and associated circuits. Chapter 18 contains details about colour receiver circuit analysis and trouble-shooting while included in Chapter 19 are the concepts of teletext, viewdate, TV game, Video Cassette Recording (VCR) and playback techniques. Chapter 20 contains elements of digital TV transmission and reception.

The material is presented in an easy-to-grasp form. Though it is assumed that the readers are already acquainted with the basics of TV technology, the treatment is such that anybody possessing basic knowledge of electronics circuitry and building blocks of electronics will find no difficulty in understanding the subjects. Review questions included at the end of every chapter will facilitate testing of student's knowledge. The book will certainly fulfil the long-felt need of electronics engineering students, TV engineers and technicians. The book will also prove useful to colour TV research workers and post-graduate students offering electronics.

P.K. Mukherjee

BOOK REVIEWS

DIGITAL CONTROL ENGINEERING *by* M. Gopal, *Wiley Eastern Ltd.*, 4835/24, Ansari Road, Daryaganj, N. Delhi—110002. Pp. 535

THE book is intended for one semester course of senior level under-graduate students or first year graduate level students. The material presented in 9 chapters is very concise and comprehensive.

The entire coverage of the course material can be grouped into two parts. The first part of the books deals with the classical control theory. The well established concepts of control theory, e.g., conversion techniques (analog to digital and digital to analog), the sampling theorem, signal reconstruction, Laplace transform and z-transform are discussed at length so as to make the reader familiar with the basic concepts. This material has been nicely presented though some of it has been covered well in author's earlier texts.

The second portion in which the state space technique is presented is much more theoretical. The author discusses the digital system design based on this technique. The presentation is nice and lucid and is of more theoretical interest. One whole chapter is devoted to the study of self tuning control system. Rest of the text deals with processor based digital control system. Here the whole treatment is centered around the most popular INTEL 8 bit processor 8085. Two case studies done at IIT Delhi are presented. Software, package CADPAC developed at IIT Delhi is given in brief. The listing of programmes presented in these chapters make the book more useful to the reader. Appendix at the end of some chapters and also at the end of the book cover an excellent background material so as to make the book self sufficient. Another important feature of the book is that the problem sections appearing at the end of some of the chapters are a good collection.

There are a number of references at the end, which include some very recent ones. Clarity of figures is another feature of the book. The entire book can serve the student as well as theoreticians. The book will be a nice addition to the already available texts and will prove to benefit the students at large.

S.S. Rajput

GENERAL SCIENCE—Book one to five, *by* Charles Windridge, *Pustak Mahal,* Khari Baoli, Delhi-110006, pp. 88, 88, 88, 88, 112, Rs. 12 each.

DO you know the composition of air? Or, how do liquids and solids contract and expand? Or, how does a fire alarm work? What are levers? How do plants grow ? How do animals defend themselves ? Or, how do they reproduce? Answers to these and several such questions on topics ranging from Astronomy to Zoology are dealt with in the series of books under review.

In each book different topics from Biology, Physics and Chemistry are dealt with. A wide variety of topics are briefly but clearly described and are followed by several self-explanatory line-drawings (on facing page) which are useful in understanding the subject matter. The books start with the most simple concepts and then go over to difficult ones. Basic facts are presented in such a way as to encourage children to take up some purposeful activities at home. They can perform simple experiments mentioned in the book using material available at home. At the end of every book exercises are given to provide practice in written work, drawing, use of scientific terms and calculations, etc., and to revise one's understanding of a subject.

These original British books, published at moderate price in India, would be useful to students in the age group eleven to sixteen.

N.R. Mankad

THE EYE OF THE QUEEN *by* Phillip Mann, *Grafton Books,* (Available from: *Rupa & Co.,* 3831, Pataudi House Rd., Daryaganj, New Delhi-110002), Pp. 264, £ 2.95.

ASTRONOMERS have been searching for earth-like planets and civilizations beyond earth for a long time. The elusive UFOs sometimes draw their attention to the possible visits of creature-from-the-other-worlds. In this context, the science fiction writers have outdone astronomers. Crossing the barriers of time and space they 'create' before us worlds full of super-intelligent and powerful creatures. The science fiction under review is set in the latter half of the 21st century. A ship from the planet Pe-Ellia approaches earth. Pe-Ellians request the 'contact linguist' Marius Thorndyke to visit their planet. Thorndyke alongwith another contact linguist Thomas Mnaba lands on the bizarre planet of Pe-Ellia. The air here is warm like a greenhouse. Thorndyke and Mnaba start looking into the nature of alien Pe-Ellians. They are nearly twice the size of human beings, powerful yet docile and strongly telepathic. Pe-Ellians abhor the waves of anger and hate because they can damage and destroy them. Pe-Ellians grow in seven stages and in between slough off their skin like the moulting process in insect larvae. Anus and independent reproductive organs are absent. For excretion they immerse themselves in a "resting bath" filled with a silvery liquid. This silver bath interacts with the skin and draws the waste from Pe-Ellians. The Queen is responsible for continuation of life on Pe-Ellia. For Pe-Ellians, life is not precious because death is not the end of life for them. Despite

Mnaba's opposition Thorndyke starts adopting the Pe-Ellian system of life. As time passes by, he unknowingly slips into the alien way of life.

Science-fiction writers often project an advanced alien civilization. This perhaps results from the unconscious belief that human beings are an inferior species. Through the legendary character Thorndyke, the author conveys that human brain is an ill-balanced and blighted organ. The rational part of the brain is dominated by darker primitive instincts.

The author has been able make his extra-ordinary giant aliens real. Reading this fascinating book is like a visit to the Pe-Ellian civilization.

Ravindra Verma

TEXT BOOK ON PHYSICS *by* B.B. Tripathy, *Gitanjali Prakashan,* Khazanchi Road, Patna-800004, Pp. 546, Rs. 60.00.

THE book under review is the second, i.e., Part-II in the series of two volumes. The review about the first volume (Part—I) appeared in an earlier issue (see *S.R.*, January, 1986). The book has thirty chapters in all. The topics covered in the book are light, electrostatics, modern physics, current electricity and magnetism.

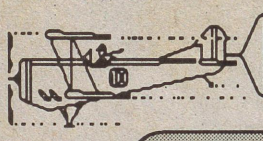
The book has been written in a lucid and simple language. Multiple-choice, short-answer and long-answer types of questions and exercises with their answers have been included at the end of every chapter. Also, included in various chapters are solved numerical examples, which will be of great value to students.

The book is written primarily to cater to the needs of Intermediate students and students at the plus two level under the new scheme of education. However, it will also benefit those students who intend to appear in various competitive examinations such as I.I.T., Engineering and Medical Entrance, etc. To increase the utility of the book further, some more difficult problems in the form of solved exercises should be added.

P.K. Mukherjee

Book Received

1. **FOUNDATIONS OF ELECTRONICS** *by* **O. Chattopadhyay, P.C. Rakshit, B. Saha & N.N. Purkail,** *Wiley Eastern Ltd.,* **4835/24, Ansari Road, Daryaganj, New Delhi-110002, Pp. 546, Rs 45.00**
2. **COMPUTERS IN MEDICINE** *by* **R.D. Lele,** *Tata McGraw-Hill Publishing Co. Ltd.,* **4/12, Asaf Ali Road, N. Delhi-110002, Pp. 248, (Hardbound) Price not stated**
3. **BASIC COMPUTER PROGRAMMING** *by* **Er. V.K. Jain** *Pustak Mahal* Khari Baoli, Delhi-110006, Pp. 169, Rs 24.00
4. **COMPUTER FOR BEGINNERS** *By* **Er. V.K. Jain,** *Pustak Mahal* **(address as above), Pp. 192, Rs 24.00**
5. **WAVES AND OSCILLATIONS (SOUND)** *by* **S.R. Shankara Narayana,** *Sultan Chand & Sons,* **23, Daryaganj, N. Delhi-110002, Pp. 752, Rs. 13.50**
6. **MECHANICS AND PROPERTIES OF MATTER** *by* **S.R. Shankara Narayana,** *Sultan Chand & Sons* **(address as above) Pp. 596, Rs. 40.00**



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SCIENTIFIC REMINISCENCES

CHANDRASEKHAR VENKATA RAMAN

By Prof. Dr. Meghnad Saha, D.Sc., F. R. S.
University Of Allahabad

IN THE YEAR 1913, THE writer of this article, who was then a student in the Presidency College, Calcutta, went to attend a lecture at the Indian Association for the Cultivation of Science at 210, Bowbazar Street, Calcutta. He does not remember the name of the lecturer or the subject of the lecture. But he remembers that he noticed there for the first time a tall, stalwart, turbaned figure apparently a South Indian, moving with the vivacity of Nataraja Siva, so familiar in South Indian Iconography, and making the lecturer rather uneasy by his penetrating questions. This figure was no other than Sir C. V. Raman, then an officer in the finance department, who was destined to be the first Indian to win the much-coveted Nobel prize in Science, seventeen years later.

HIS ANCESTORS.

The ancestors of Sir C. V. Raman came from the Tanjore district, and as he once informed the writer of this article, his grandfather took a trip on foot to Nuddeah in Bengal to learn the Nyaya Philosophy. His father was a Professor of Vizianagram in the Andhradesa where Sir C. V. Raman saw the light of day nearly forty-five years ago. So he is claimed both by Tamils and Telugus to be belonging to them. But in reality he belongs to none of these people, but properly to Bengal, which was the first to discover his genius, and provide him with a laboratory where he could give free play to his talents.

EARLY LIFE.

He distinguished himself in his early School and College days, carrying away prizes and scholarships. While a student of the M.Sc., class at the Madras Presidency College, he carried out several improvements on Melde's experiments on the vibration of strings, and his originality of mind attracted the notice of Mr. Jones, the Professor of Physics, for whom Sir C. V. Raman cherishes the highest regard. Mr. Jones offered him a job in the educational department, but as during these granting him leave for joining his new post, his official chief wished him success in his new venture as 'Experimental Professor of Physics (The official designation was Professor of Experimental Physics).

Raman joined his post in 1917, and from that time, he had devoted all his time and energy to original research in Physics in the Indian Association for the Cultivation of Science. He attracted students from all parts of India, and many of his students achieved great distinction in original work. His laboratory is permeated with his dynamic personality—and work is going on incessantly from morning till night. He seems to have taken as his adage the saying of the great Frenchman, Pasteur: 'Travaillez, mes enfants, toujours travaillez" (Work, my boys, always work).

"RAMAN EFFECT."

The crowning achievement of his life came in 1928 when he discovered "Combination Scattering," now called fittingly after him "Raman Effect". This was not due to a mere stroke of good fortune but was the culmination of years of hard and continuous work. The blue colour of the sky and the sea has always impressed poets and authors, but a Scientific explanation of it was first given by Lord Rayleigh, and was supported by the experiments of Tyndall. Lord Rayleigh showed that the phenomena was due to the breaking up of light waves by the molecules which compose our atmosphere. The sky appears blue because more blue light is thrown side ways than red light.

Raman's interest in the subject seems to have been roused by experiments which were carried out about 13 years ago by the Hon'ble T. Strutt, the present Lord Rayleigh (and son of the first Lord Rayleigh) for experimentally demonstrating the validity of his father's theories. He devised very delicate apparatus for experimentally investigating the scattering by molecules of different types and in co-operation with his numerous students carried out hundreds of Niels Bohr, had worked out a theory of refraction on these bases. Experiments to verify the theory were carried out at Bohr's laboratory, but without success. It was reserved for an Indian to achieve the first success in these lines.

This is rather strange, because European writers are never tired of describing the Indians as given over completely to metaphysical speculations, and possessed of little practical abilities. Here were the roles reversed —an Indian giving the first practical effect to the theoretical speculation of European savants, which they themselves have been unable to verify!

The prediction of this effect by other savants does not take away from Raman the great credit which is rightly due to him. An analogy will do; the fact that the Earth is round was first said to be clearly enunciated by the Pythagoreans particularly by Anaxogoras who flourished in the 6th century B. C. The radius of the earth was actually measured by Eratosthenes of Alexandria in the 3rd century B. C., by using the same methods which are now used in trigonometric surveys all over the world. But these predictions do not certainly take away from the great credit which is due to Columbus and other great navigators who undertook perilous voyages in unknown seas, in moral support of these theories. Credit is always due to the man who can actually turn a speculation into a practical reality.

THE NEW HONOUR

After twenty-five years' stay at Calcutta, Professor Raman is called away to his native South for shouldering the responsibility of the Indian Institute of Science at Bangalore. He leaves with the best wishes from the people of the land of his adoption, who sincerely hope that his new mission will be as much crowned with success as his labours at Calcutta had been. Though he is gradually passing into the afternoon of life, his store of dynamic energy shows no sign of deterioration, and it is

times, all the higher posts in the educational service were exclusively reserved for Europeans, young Raman did not find the job sufficiently tempting, and instead of accepting it, went for the Finance Competitive Examination. He was successful and when barely 19, found himself in the service of the Government of India with a starting salary of Rs. 500, and with prospects of going up to Rs. 3,000 per month, and adding rupees, annas and pies for the benefit of the bureaucracy.

But neither the depressing atmosphere of the finance service, nor the security of an easy life could dry up Raman's superabundance of energy. He astonished the department, particularly his official chief by retaining his interests in physics, and continuing to pubish original papers in European journals. In 1912, when he was transferred to Calcutta, he found a place for work in the Indian Association for the Cultivation of Science, a private organisation for spread of scientific knowledge founded by Dr. Mahendra Lal Sircar, a leading medical practitioner of Calcutta. Like Count Rumford who founded the Royal Institution of Great Britain with the object of devising a method for the cheap feeding of the poor by scientific methods, Dr. Sircar had founded the Science Association in the hope Science would solve the problems of poverty, disease and superstition in his country. The Royal Institution was the nursing ground of the geniuses of Davy and Faraday; the Science Association became the nursing ground of the genius of Raman, and will probably continue to produce more scientific worthies in future times.

IN CALCUTTA.

In 1912, the Calcutta University was fortunate to get two princely gifts from Sir T. N. Palit and Sir R. B. Ghosh, two eminent Calcutta lawyers, for the foundation of a number of chairs for the Calcutta University. But they found great difficulty in the choice of suitable Indians who could fill up worthily these chairs. At last Sir Asutosh Mukherjee, then Vice-Chancellor of the Calcutta University and a keen 'fisher of men' pitched his choice on Raman, and was able to induce him to forsake the easy pastures of the finance department for perilous explorations in the unknown land of Science, under the flag of a disguised Swaraj regime. To his colleagues in the finance service, the adve ture appeared to be not only imprudent, but destined to failure, and while

experiments on these lines. In course of these investigations he was troubled by experiences of a new kind. He found that light seems to be modified in its colour when scattered by matter. What happens is this:—When light falls on matter, which is itself excited by heat or any other agency, the electromagnetic vibrations which constitute light become locked up with the vibrations of matter, and is profoundly modified when it comes out. But this modification cannot be detected if white light be used, because white light is a jumble of many lights and the modified lights gets lost in the medley crowd. So light of one single colour has to be used, and the modified light has to be analysed by a spectroscope. This crucial experiment was carried out by Raman and Krishna in 1928, and was immediately successful.

EFFECT OF THE DISCOVERY.

The effect of this discovery on the Scientific world was immense, for it not only brought to light new phenomena, but it opened a new way for investigating the properties of matter. The importance of the result was first recognised by P. Pringshein, Professor at Berlin who in an article in the German Naturwissenschaft, gave an account of the discovery, and called attention to its great importance in molecular physics. From this time onwards, the interest in the work has remained unabated, and investigations on Raman Spectrum (Spectrum of combination scattering due to molecules) have become common features in journals of Physics and Chemistry. A great amount of these contributions has come from Prof. Ramon's own Laboratory. His great services to Science were recognised by the award of a Nobel Prize in 1930, and strange to say, even that prosaic body, the Government of India, seemed to signify its appreciation by conferring on him a knighthood in 1929, a distinction usually reserved for bureaucrats and politicians of a class whose activities are of an approved type.

As is usual in these days, controversies regarding precedence immediately arose after the announcement of the discovery, for two Russian workers, Landsberk and Mendelstamm had been working on similar lines and had been forestalled by Raman by only two months. An Austrian Professor, Dr. Smekal, had predicted the effect from thermodynamical reasoning, and Kramers and Heisenberg, two pupils of the famous

its sign of deterioration, and is hoped that they will be more fruitful in the new land of venture!