THE AUTHOR

Professor M. Vijayan is a leading Indian structural biologist with considerable international presence. He has been largely instrumental in initiating and nurturing biological macromolecular crystallography in India. A majority of the research groups in this area in the country are led by his students and their descendants. He has made significant contributions pertaining to supramolecular association and its implications to chemical evolution and origin of life; lectins and protein–carbohydrate interactions; protein hydration and its consequences; and mycobacterial, especially TB, proteins. He, along with colleagues, orchestrated a programme on structural biology of microbial pathogens and coordinated an effort to create an Indian platform for structure based design of inhibitors of TB proteins, with the eventual aim of contributing to drug development. His leadership roles in Indian science, and to an extent in international science, extend well beyond the chosen areas of crystallography and biophysics. His extensive engagement with science academies has encompassed the Presidentship of the Indian National Science Academy. He has been deeply involved in the activities of the science and technology departments of the government and dozens of institutions across the country. Professor Vijayan's efforts have been characterized by national commitment and emphasis on mentoring.

Science and technology constitute a pre-eminent tool to enhance the wellbeing of people. Science is also a way of life, an approach to problems and a celebration of excellence. Promotion of excellence is a hallmark of a healthy civilization. This civilizational aspect of science is of paramount importance. In addition to helping the material welfare of the human kind, science also helps lead us into that heaven of freedom "Where the clear stream of reason has not lost its way into the dreary desert sand of dead habit".

In order to unleash the creative potential of Indian science, we need a vibrant, resilient and sensitive system which is less bureaucratic, less hierarchical, more autonomous and more participatory.

– M. Vijayan

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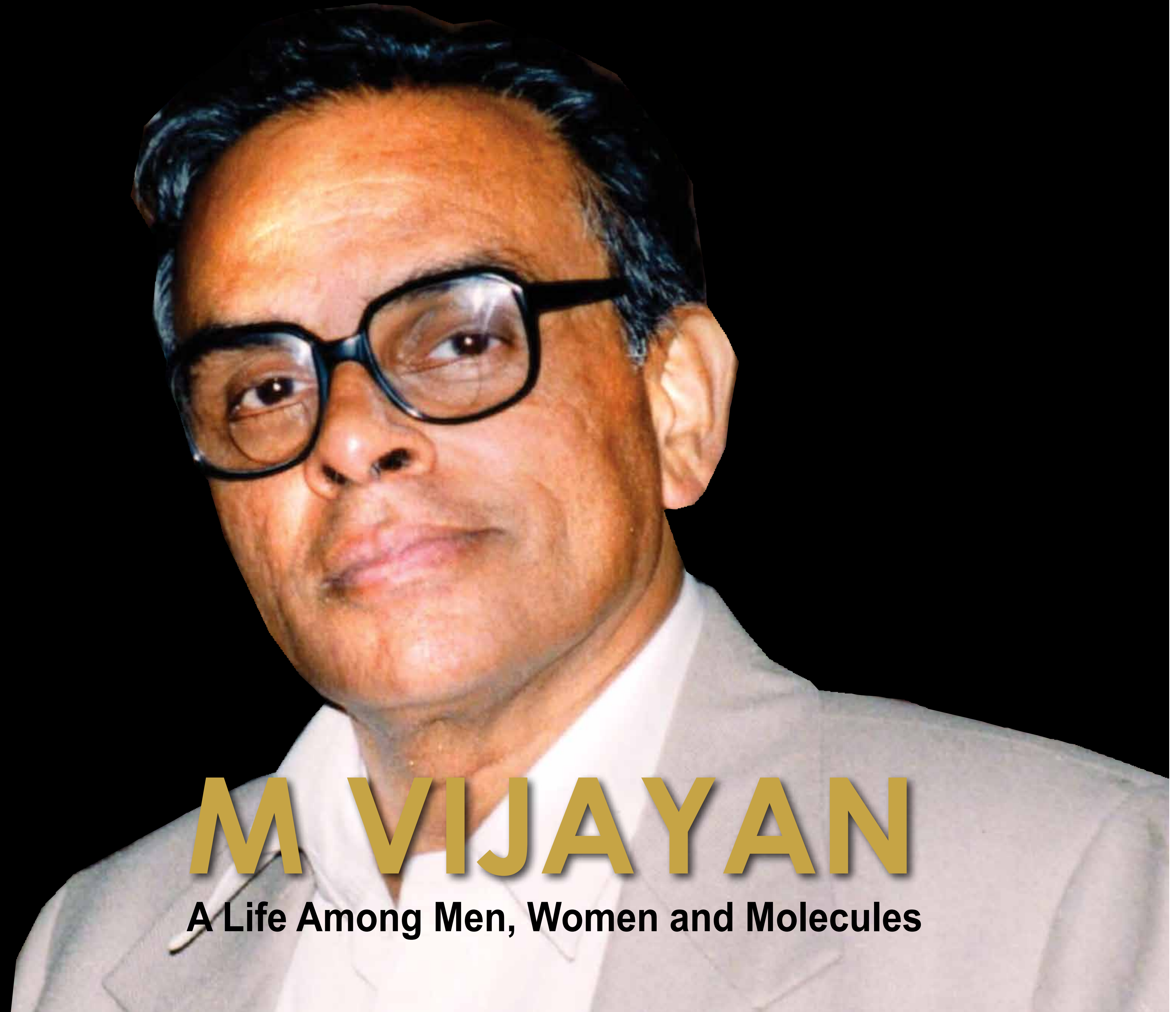
MEMOIRS • M Vijayan



M VIJAYAN

A Life Among Men, Women and Molecules

ABOUT THE BOOK

Prof. Mamannamana Vijayan, is one of the more distinguished Scientists of India, celebrated and revered for his contributions as an outstanding structural biologist, a passionate researcher, and an enthusiastic teacher/mentor, who practiced the paradigm that results are important but human beings are more important.

Prof. Vijayan has been an integral and important part of Indian Science firmament and has played a key role in many important decisions that the Indian Science took. This book by him is not only a *tour-de-force* of the development of macro-molecular crystallography largely developed by him in India, but also a narrative of how Indian Science evolved in a poor Nation that gained freedom after two centuries of colonial exploitation, ravaged by the communal holocaust and with little resources, to a Nation aiming to travel to Moon and Mars.

Written in an engaging manner to the extent that one would find it difficult to leave the book, after beginning to read it, it provides a fascinating account of various facets of Indian Science, their evolution and the issues that need to be addressed. Author's poignant observations like, *science has gone out of main stream national discourse*, makes one think of the whole fabric of Science and Scientific research in India. He communicates his vision with passion.

This book is a narrative of Indian Science by; a person whose scientific life has been of a large magnitude; a Nationalist with deep concerns for the world around him and, a humane human with an innate desire of using the science for the wellbeing of all.

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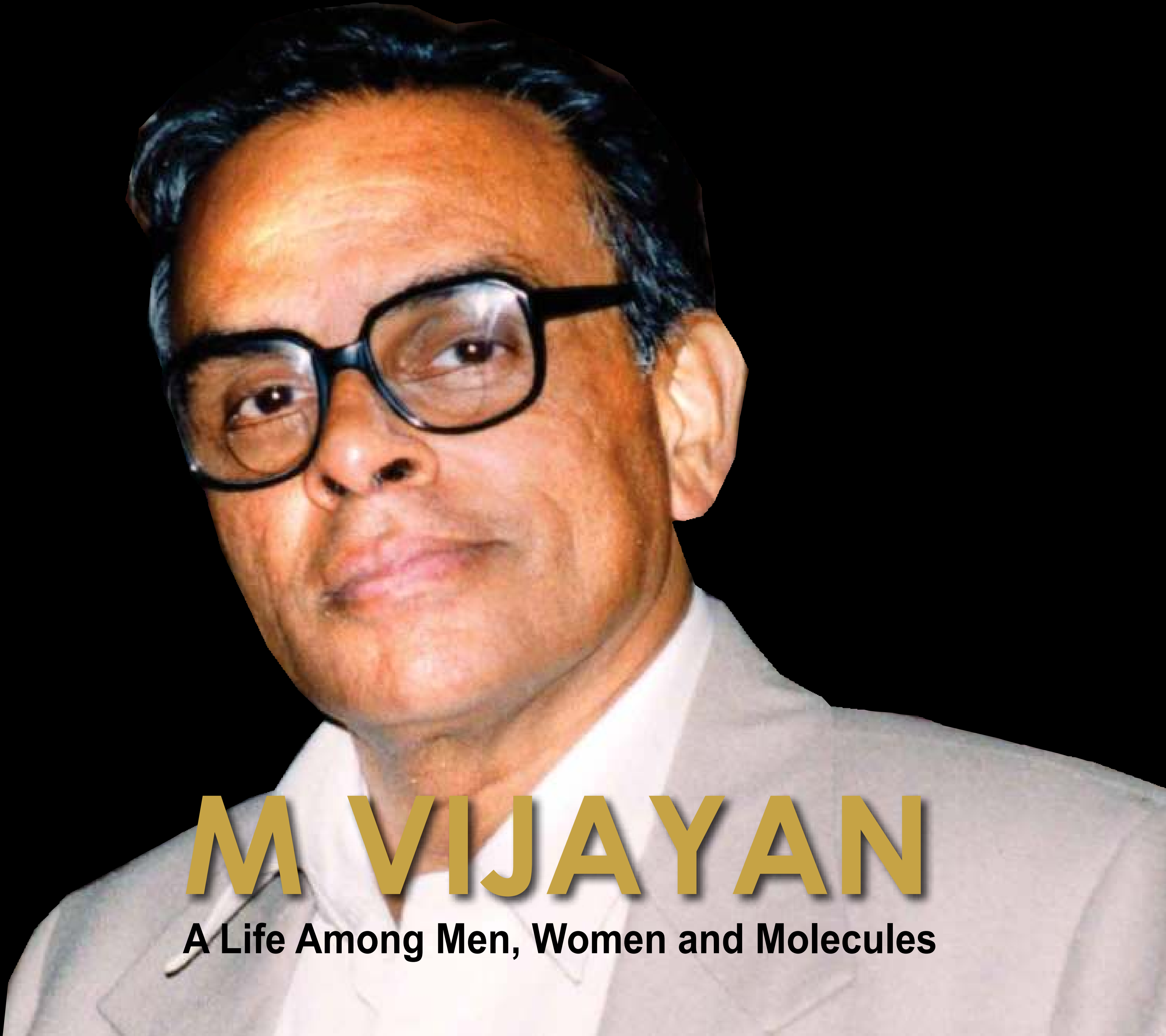

M VIJAYAN

A Life Among Men, Women and Molecules

MAMANNAMANA VIJAYAN

A Life among Men, Women and Molecules

Memoirs of an Indian Scientist

Mamannamana Vijayan

A Life among Men, Women and Molecules

Memoirs of an Indian Scientist

Edited and Coordinated by

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FOREWORD

History of science is a fascinating study because it recognizes the institutions of the past, their ethos and the characters that helped the institutions to blossom through triumphs and tragedies. Memoirs of any discipline in science are of paramount importance because the lesson in history helps the present and the future to grow. The Indian National Science Academy aspires to nurture the theme of history of science through various approaches. As the fallout of such initiatives, biographies of eminent scientists of India are of great interest since they paint a landscape of the times represented, along with an account of the scientific endeavours of the scientist concerned.

The incentive to publish this memoir of Dr. Mamannamana Vijayan was to capture a period of a scientific journey, covering a great body of work on crystallography in the country. Prof. Vijayan's tenure as a student at the Allahabad University physics department, a department with a distinguished history once headed by stalwarts like Meghnad Saha and K.S. Krishnan and details of his stay at the Physics Department of the Indian Institute of Science, founded by Sir C.V. Raman will make interesting reading for students and teachers of crystallography. It is also a chronicle of the times of stalwarts like Satish Dhawan and R.S. Krishnan and an account of the efforts of various crystallographers who built an excellent group doing cutting edge research at the Indian Institute of Science. Prof. Vijayan had close association with Prof. G.N. Ramachandran, one of the most brilliant scientists of the 20th century doing pioneering work in the field of protein structure, when they were faculty colleagues at the Molecular Biophysics unit of the Institute founded by the latter. Prof. Vijayan interacted with him often and was surely influenced by this giant in science of the times.

How Prof. Vijayan started his independent career at the Indian Institute of Science through exploration of the fundamental aspects of molecular interactions using x-ray crystallography as a tool is an engaging story and a part of history of the evolution of the field of crystallography in India. Prior to his joining the Indian Institute of Science, he worked with Prof. Dorothy Hodgkin at Oxford who had a profound influence on him. The excitement of working at such a vibrant laboratory endowed with a Nobel Prize, detailed by him would certainly be of great interest and motivating for students entering into the orbit of crystallography.

Prof. Vijayan is an outstanding structural biologist, teacher extraordinaire, a passionate researcher, an enthusiastic mentor, an able administrator and much more. I have known him for about three decades and have experienced his contributions to sustain the field of structural biology in India. His qualities as a compassionate human are to be much appreciated. Prof. Vijayan's novel contributions in the area of structure and carbohydrate binding properties of lectins, the function of hydration in the mobility and action of proteins, structural biology of mycobacterial proteins, molecular recognition and aggregation of amino acids and peptides, and their probable evolutionary implications form a formidable array of work worthy of bringing in the form of a narrative best told by the scientist himself.

Everyone loves an attractive story. We hope that this autobiography inspires young scientists where they may see the world in new ways and discover ideas and approaches that one can evolve in one's own life. It also tells us why we should collect papers and works of scientists to create a repertoire of treasure for the future students of science and history alike.

Chandrima Shaha
President, INSA

PREFACE

The idea of writing the memoirs was first mooted years ago by my friend (late) N Seshagiri. The contributions of Seshagiri to the IT revolution of India, including in his capacity as the Founder Director General of the National Informatics Centre (NIC) New Delhi, are well known. He also had an abiding interest in Biophysics. He strongly felt that I should put on record the story of the initiation and development of macromolecular crystallography in India. I was too busy with my research and organisational responsibilities to undertake this task. I got some free time only when I was undergoing treatment in an Ayurvedic hospital in 2013. Then I realised that I have had an interesting past in Kerala during my early youth. I wrote about my life during that period till 1961, in Malayalam. I sent the manuscript to M.P. Parameswaran, an outstanding leader of Peoples' Science movement and a leading light of Kerala Sastra Sahitya Parishad (KSSP) and to Kavumbai Balakrishnan who efficiently handles the publication activities of KSSP. They asked me to write my memoirs concerning the rest of my life as well. I was then not ready to do so. As a compromise, I included in the Malayalam memoirs, my life as a student at Allahabad University and the Indian Institute of Science, Bengaluru and my experiences during the stint as a post-doctoral fellow in Dorothy Hodgkin's laboratory in Oxford. That brought the story up to 1971 when I started my independent research career. The book with a Foreword by the well-known historian Rajan Gurukkal was published by KSSP. It was released by M.A. Baby, former Minister of Education and Culture in the Government of Kerala, in 2016 at a function held in the premises of Kerala Sahitya Academy at Thrissur.

The idea of writing the full-length memoirs covering the whole of my life and career still germinated in my mind. In the meantime, my health was deteriorating on account of a neurodegenerative disorder a la Stephen Hawking.

By the end of 2018, I was unable to write or type. I could still speak reasonably well. It was then that I started dictating my memoirs to my wife, Kalyani, who also helped me with the composition of the narrative. The material was then typed by my Secretary, C Pankaja. I had the help of G. Lalitha, my former Secretary when I was the Associate Director of the Institute, during the final stages of the preparation of the manuscript. T. Radha Krishnan who is among those involved in looking after me, was also of great help in putting the material together. The figures given in Chapters 8 and 10 were prepared by my graduate student N. Sivaji. Another graduate student, Anju Paul and my daughter, Devi were of help in finalising the manuscript. Association with my younger colleague B. Gopal has been central to my professional life during the past few years. It would have been impossible to write this book without his overall support.

Although my main original career objective was the initiation and development of macromolecular crystallography in India, in the event, I got involved in a whole spectrum of scientific and related activities in the country and abroad. I have kept the narration of the activities substantially non-technical. Only parts of Chapters 8 and 10 are technical. The continuity of the narration would remain unaffected even if these parts are skipped.

The trajectory of my life started in Kerala in a community in transition and was followed by a short phase of intense political activism in my early youth. The essentials of the world view, commitments and values acquired during those formative years remained with me throughout my life. During my transformation as an Indian Scientist, traversed through Allahabad University, Indian Institute of Science and Oxford University, these evolved and became more nuanced. In my role as an Indian Scientist, India and Science have been equally important. My Indian identity was not only never in conflict with, but has been complementary to, my international and regional identities. During my long career, I have been associated with a number of organisations and institutions. I highly value the friendships I acquired through these associations. What has given me the highest satisfaction is the opportunity I have had for mentoring a large number of scientists and, to an extent, an area of science in the country. The story I have tried to narrate in this book is as much that of the organisations, institutions and individuals whom I have interacted with, as that of my life and endeavours.

M.Vijayan

M. Vijayan

Bengaluru
January, 2020

ACKNOWLEDGEMENTS

The contributions of those who helped in preparing the manuscript have been acknowledged in the Preface. In this effort, I have been benefitted by the advice and encouragement of Professor Rajan Gurukkal, the historian. It is appropriate that the Memoirs are being published by the Indian National Science Academy, an institution with which I have had a long association. I am indebted to Dr. Alok Moitra whose initiative led to the publication of the book by the Academy. I thank Dr. Chandrima Shaha for agreeing to do so and her constant support during the preparation of the book. I owe a huge debt of gratitude to Professor Ashok Singhvi for his total involvement and creative interventions in the processing of the manuscript. I thank Ms. Manisha Shrivastava of Angkor Publishers (P) Ltd. for her invaluable help in the design and production of the book. I have quoted in the book extensively from my articles in Current Science, which I have used often for expressing my views on general issues.


M.Vijayan

1

THE BEGINNINGS

Nambudiris in transition. Family background

Nambudiris are brahmins of Kerala. Although historical evidences are hazy, many consider Adi Sankara, the great philosopher and intellectual giant, who is believed to have born in Kaladi in Kerala in the eighth century, to have been a Nambudiri. If true, he would be the greatest Nambudiri, besides very much else, of all times. Be that as it may, the most famous Nambudiri of modern times is the late E.M.S. Nambudiripad. He was a legendary communist leader of India. He was also the first Chief Minister of Kerala, after the state was formed in 1956. EMS and the movements he led were largely instrumental in liberating Nambudiris from the debilitating customs and practices which then prevailed. This was in part achieved through the reformist movement among Nambudiris in the first half of the 20th century and later through the legislations of the communist government. The reform movement was in step with the national movement for the liberation of India. It was when the reform movement was in its last phase, when orthodoxy and modernity co-existed in perpetual conflict, that I was born in a Nambudiri family, on October 16, 1941. The time was then only a few years away from August, 1947, when India woke to "life and freedom". The world was then in the middle of a great war which ushered in momentous changes in the global order.

As in the case of brahmins elsewhere in the country, the track record of Nambudiris over centuries has a mixture of negative and positive features. On one hand, they were the custodians of oppressive orthodoxy. On the other hand, they made outstanding contributions to intellectual pursuits and promotion of art and culture. From my conversation with elders, I have a fair picture of the state of the community from the dawn of the 20th century. The social organization of the Kerala society was somewhat peculiar. Among the upper castes, Nambudiris followed the patrilinear system. Others like the royal families, castes involved in serving temples and Nairs, followed the matrilinear system. Only the eldest son in a Nambudiri family married Nambudiri women. The norm was to have three wives, often of different ages. The younger sons married women from royal families, families associated with temples, Nair families, etc. Children from such marriages belonged to the mother's family. Such an arrangement was advantageous to Nambudiri men, in two different ways. First, Nambudiri property did not get divided. Secondly, the local kings, chiefs and other important people in the upper crust were mostly children of Nambudiris and owed allegiance to them. Those who suffered in this arrangement were Nambudiri women. They were also obliged to observe strict *purdah* and were confined to their homes. Polygamy coupled with strict *purdah* and confinement within the interiors of the household were real curses on Nambudiri women.

Nambudiri men were also substantially removed from mainstream activities. They primarily depended on rent from lands they owned, but not cultivated. Most of them were not employed in any other way. That allowed them to engage in intellectual pursuits and promote art and cultural activities. Unlike Tamil brahmins, Nambudiris did not take to modern ("English") education. In fact, English was considered by many as an uncouth language. This meant that Nambudiris were not in competition with anybody else for jobs. That was one factor that earned the goodwill of others for Nambudiris. Furthermore, by and large, they led simple lives, even those who were rich. Again, in general, cruelty was not part of the Nambudiri character and subordinates and others were treated well. Therefore, Nambudiris were treated with respect and consideration by others. However, the fact remains that the life of Nambudiris was based on feudal exploitation.

Revolt against the social and family order among Nambudiris, from within the community, began to develop by the early days of the 20th century. The main thrust of the reformist movement was against polygamy, *purdah* and apathy towards modernity as evidenced by opposition to modern education. As in the national movement, there were different levels of radicalism among the reformists. EMS entered public life through this reformist movement and he has always been among the more radical section of it. Very soon, he became a Congress leader, then a leader of the Congress Socialist Party and finally a communist by the end of the 1930s. The most memorable event in the course of his involvement with the Nambudiri reformist movement, was the famous speech entitled "Make Nambudiri a human being", delivered at a place called Ongallur in 1944. I vaguely recall listening to this speech as a young child when I was in the gathering along with my parents. I was not old enough to understand the subject. What struck me was the stammer of the speaker and the extraordinary difficulty with which he spoke.

The efforts for bringing Nambudiris into the mainstream of society was completed in the late 1950s when the Kerala ministry under the leadership of EMS began the process of abolishing land-lordism and bringing in agricultural reforms. The feudalistic past of Nambudiris is now only a distant memory and they now constitute a progressive, well-educated, thriving community.

There was considerable heterogeneity among Nambudiris in financial status. There were wealthy Nambudiris and poor ones who eked out their lives with great difficulty. Then there were "Adhyans" and "Asyans". As a rule of thumb, Adhyans were wealthy and powerful, while Asyans were comparatively less well-off and scholarly. There were considerable differences in the customs and practices of the two groups. There was also some underlying rivalry between the two groups. A majority of Nambudiris, cutting across Adhyans and Asyans, were Rig Vedis; a substantial number practiced Yajur Veda, while Sāma Vedis were in a minority. Then there was a group which customarily did not learn any Veda. The last group was considered to be at a lower level in the hierarchy among Nambudiris. All these divisions were significant in the Nambudiri community even during the middle of the twentieth century. They have now become almost irrelevant after the reformation in the community, referred to earlier. Many in the present generation of Nambudiris may not even know these distinctions. Until roughly the middle of the twentieth century, joint family system prevailed among Nambudiris, as indeed among many other communities, when members from several lineages lived under the same roof. Now it is a thing of the past. Nuclear families now prevail. However, the relationship among the nuclear segments of the same large family continues to be strong. The relationship among the relatives also tends to be strong among Nambudiris of today.

My paternal ancestors belonged to an extended family called Muttathukattil Mamanna Mana, located in a village called Panjal in central Kerala. They had reasonable landed property. Among other things, they constituted a family traditionally involved in teaching Sāma Veda to families who followed this Veda. Therefore, many Sāma Vedi Nambudiris were their students who held the members of my family in high esteem. Among the elders of my family I know of, the one who made a difference in the lives of my father and his descendents was the eldest brother of my father named Itti Ravi Nambudiri, whom I and my siblings called Valiachchan. He was very pious and steeped in tradition. However, he was also modern in outlook in many respects. These two aspects combined in him harmoniously. When he was young, he was keen to acquire modern school education. However, his parents did not allow him to do so. Subsequently he was responsible for educating my father.

Valiachchan went on to become an influential figure not only in the community, but also among different scholarly groups in India and abroad. Naturally he had a large number of students whom he taught Sāma Veda. He brought about many reforms in the rituals that he presided over. He travelled widely in the country. He was involved in organizing more than one *yagna*, with the support of scholars abroad, for their historic importance. In spite of the fact that he spoke only Malayalam and probably some Sanskrit, he has influenced many leading scholars in India and abroad. For instance, as narrated later, I was thrilled when Kapila Vatsyayan listed Valiachchan among those who influenced her, when she gave a public lecture in Delhi in 2009, in connection with the Platinum Jubilee celebrations of the Indian National Science Academy, while I was its President.

My father was born in October 1910. He completed all the rigorous rituals that a Nambudiri boy was expected to go through by the time he was fourteen years of age. It was only then that he commenced his school education at Thrissur in the fourth standard. He completed his school education at Thrissur. Naturally, he was deeply influenced by the reform movement among Nambudiris. Moreover, when he was studying in high school classes, EMS, a couple of years older than him, was a student of the St. Thomas College at Thrissur. They, along with a few other young Nambudiris, stayed in the same lodge. Like Valiachchan, EMS was a great influence in his life. He participated actively in the reform movement. In his political convictions, he followed the path of EMS, although he was not an active participant in politics. He remained a steadfast communist sympathizer all his life. He was on familiar terms with many of the legendary communist leaders of Kerala and earned their respect.

After schooling at Thrissur, my father studied the Intermediate course at the Maharaja's College, Ernakulam and later took his B.Sc. degree from Annamalai University. He was among the first few Nambudiri graduates. After graduation, he joined as a teacher in CNN High School at Cherpu near Thrissur. He continued in the same school until his retirement as headmaster in 1970. My father's name was Subramanian. He was generally known as MS master or M.S. Nambudiri. It was when he was a young teacher at Cherpu, that he married my mother, Umadevi. Myself, my sister Indira, and two brothers, Ravindran and Surendran, were all born and brought up at Cherpu.

My mother had a very different kind of family background. On account of a quirk of destiny, she spent most of her adult life before marriage in her grandparents' house, Akavoor mana, near Aluva. Akavoor mana was a distinguished, powerful, wealthy Adhyan family. They had landed property in several places across southern Kerala. I recall that when I was a child, they had two baby elephants as pets. Despite being very wealthy, their lifestyle, like most other Nambudiris, was simple. Also they treated their subordinates and others with great kindness and consideration. They were also great patrons of art and culture. Most of my mother's relatives also belonged to such well known, wealthy families.

On account of the different backgrounds of my father and mother, we followed at home a mixture of Adhyan and Asyan practices. My father did not appear to have cared for them. My mother was inclined towards Adhyan practices, although she was not averse to Asyan practices. I favoured Asyan practices primarily on account of my proclivity to gravitate towards the weaker side in any dispute. Asyans were perceived and probably really were weaker than Adhyans. In any case, the practices were never a matter of serious dispute at home.

My father grew up in an atmosphere of religious orthodoxy and practiced all the rituals, when he was a boy. Subsequently he turned out to be a non-believer and a strong communist sympathizer. However, he was very tolerant towards the mild religiosity of my mother and in fact facilitated whatever she wanted to practice. He even took my grandmother (mother's mother) on a religious pilgrimage. I often wondered why he sported a sacred thread in spite of him being a non-believer. We realized the reason for this only when he abandoned it after the passing away of Valiachchan. He wore the sacred thread till that time, only in order not to hurt Valiachchan. I myself had mixed feelings about religion. As a boy, I remember a time when I used to visit a temple every evening in wet clothes after bath, to pray. Subsequently I lost faith in temples except as cultural and community centres. Still some kind of religiosity is ingrained in the mind. I recall feeling deeply disturbed and insecure as a teenager when I read the absorbing discussion on the materialistic component of Indian philosophy in the Malayalam book, the title of which can be translated as "Soul of India", by the communist leader and theoretician K. Damodaran. Eventually I developed an approach to God and religion which is totally unorthodox but not entirely atheistic.

In a manner of speaking, every Nambudiri is related to every other in one way or another. Fortunately, we had many relatives at Cherpu itself and the boys of these related families formed a reasonably coherent group. There was another group of relatives centred around Panjal and yet another around Akavoor. The circle of friends eventually expanded to non-relatives as well. Cherpu was, and continues to be, a centre of temple festivals and we were active participants in them. The interest I then developed in elephants and different kinds of traditional orchestras of Kerala is still alive in me. Kathakali and other dance forms of Kerala claimed, and still claim, my intense attention. My intense involvement in temple festivals continued until political activity began to claim more and more of my time and attention.

The overall societal ambience of Cherpu, and probably of most of Kerala, was marked by communal harmony. When I was a boy, division of labour based on caste was still strong, but that does not appear to have led to conflict. There were substantial Christian and Muslim populations at Cherpu. The same was, and is true about Kerala as a whole. Tradition has it that St. Thomas brought Christianity to Kerala and traditional Christian families often claim to be the descendants of Nambudiri converts. Islam came to Kerala through trade with Arabs who received the patronage of local kings. Therefore, the spread of these religions was not through conquest, unlike in the case of Islam in the North. Serious communal tension was rare in Kerala. For Christians and Muslims in Kerala, the Kerala identity was as important as or more important than their religious identity. Kerala Muslims spoke Malayalam at home with a tinge of Arabic. I have never seen a Muslim woman in *purdah* when I was young. There are many castes among Hindus. As a child, I perceived Christianity and Islam more or less as two such castes. Only later I realized that they are separate religions. Our friends, especially after I began to go to school, naturally included Muslims and Christians.

Religious orthodoxy and the practice of untouchability persisted among Nambudiris when I was a boy, although they were on the wane. Normally you were supposed to take a bath before you eat or perform a religious ritual, or if you had touched a non-brahmin. Some of us, certainly I, enjoyed touching non-brahmins in front of elders as a mark of defiance! These acts of defiance were engendered by the leftist political ambience at home.

Early education

As was the normal practice then among Nambudiri families, my early education was at home. My first foray into a school was to the fourth standard. I studied for a few weeks in the fourth standard in a church school where the headmaster was a Tamil brahmin. Nobody found anything odd in a Nambudiri boy going to a church school headed by a Tamil brahmin! That is a reflection of the ambience that prevailed in Kerala. My regular school education started in the preparatory class (perhaps somewhere in between the fourth and fifth standards of today) in CNN Boys High School where my father was a teacher. I continued in the school until I obtained my S.S.L.C. By the time I reached the third form (seventh standard), I began to be an active participant in literary associations, etc. I must have been 11 or 12 at that time. I also began to get involved in student politics. I passed the S.S.L.C. examination in 1956 unremarkably.

The choice for college education was then between Sree Kerala Varma College and St. Thomas College, both at Thrissur. St. Thomas college was perhaps the more established of the two, but was known for strict discipline. The atmosphere at Kerala Varma was more liberal and was conducive for political activities. That was my main consideration for choosing that college for higher studies. The college was then under the Madras University. One year pre-university course (followed by three year degree course), instead of the two year Intermediate course (followed by two year degree course) was introduced in the year (1956) in which I joined the college. Thus, the transition from school education to college education had to be negotiated within a year. This was particularly tough on account of the change in the medium of instruction from Malayalam to English. I managed this transition with great difficulty. That was probably the only year in which I exclusively concentrated on studies!

My performance in the pre-university examination was also unremarkable. However, I obtained reasonably high marks in Physics and Mathematics. My father was of the opinion that I should try for engineering for higher studies. I wanted to do Economics as that was more in sync with my political activities. As a compromise, I joined the B.Sc. degree course in Kerala Varma with Physics as the main subject and Mathematics as the subsidiary subject. During this period, for most of the time, my interest in science was marginal. My interest was awakened only towards the end of the course when modern physics became an important component of the course. In the meantime, I was deeply involved in political activities. Despite this distraction, to my own surprise, as indeed to the surprise of many others, I managed to obtain a first class, which was difficult in those days. That, to an extent, was instrumental in changing the course of my life.

Formative years in the Left movement

During a visit in 1892, Swami Vivekananda called Kerala a 'lunatic asylum'. It was the caste system and untouchability that then prevailed in Kerala that prompted Vivekananda to say so. Many in Kerala practised unapproachability as well. The situation changed for the better primarily because of the reform movements in different communities during the second half of the 19th century and the first half of the 20th century. The reform movement among Nambudiris, referred to earlier, was one among them. The most distinguished leader of the reform movement was Sree Narayana Guru (1856-1928). His approach was steeped in vedantic tradition, but the impact was revolutionary. Some of his sayings are still quoted widely in Kerala. Some oft quoted examples are: "one caste, one religion, and one God for man"; "whichever the religion it suffices if it makes a better man"; "ask not, say not, think not caste". A major thrust of the reform movement was against the caste system. There were also legendary agitations against untouchability and for temple entry of untouchables, at least one of which was led by Mahatma Gandhi. It is in this ambience that the national movement and Left movement originated and thrived in Kerala.

Most of the participants of the reform movements became part of the national movement. For example, EMS became a Congress leader of Kerala in the 1930s. Subsequently, many leftists in Congress joined the Congress Socialist Party in the second half of the thirties. The first communist group was established clandestinely in 1937 and consisted of P. Krishna Pillai, EMS, K. Damodaran and N.C. Sekhar; all of them, however, remained in the Congress Socialist Party. In 1939, the Congress Socialist Party of Kerala converted itself into the Communist Party.

Until the middle of the twentieth century, Kerala was made of three administrative units: the princely states of Travancore and Cochin, and the then Malabar district, which was directly ruled by the British until independence, as part of the

Madras Presidency. Following the decision of the national leadership, Indian National Congress formally existed prior to independence only in Malabar. The national movement of Travancore was primarily led by the State Congress and that of Cochin by Prajamandalam. The Communist Party was effectively a pan Kerala movement. In the 1940s, the party was involved in several legendary struggles of workers and peasants. By the time of independence, the Party was a significant, though not predominant, force in Kerala. In 1948, the Congress of the Communist Party in Calcutta effected a change in the policy direction of the Party. The Party then presumed India to be ready for an armed revolution. Following the change in policy, the Party was banned all over India. During 1948-52, when the Party was proscribed, the entire leadership went underground. It, however, continued to be active among the people. In 1952, at the time of the first General Elections in India, the Communist Party emerged as a major force in Kerala. That was the time I started my political activities as a boy.

I do not remember a time when I was not interested in politics. Although my father was only a strong sympathizer of the communist cause, the atmosphere at home was decidedly political. One of my early recollections was when EMS stayed in our house when he was underground. It was important that nobody knew of his presence at home. My parents were in a quandary as to how to manage me, then a boy. Eventually, they decided that it was best to frankly explain the situation to me. I was, consequently, very reticent when I mixed with friends. I recall that I used to go and sit close to EMS, who then used to sport a big moustache as a disguise. Most of the time he was engaged in writing. Subsequently, I remember the visit to our home of many Left leaders, literary luminaries and activists. I used to sit on the sidelines and listen to their conversation. That was, in a way, part of my informal education!

The first conference I attended was that of a communist supported student organization (then not called Students' Federation as the ban on Left organizations was lifted only recently) at Thrissur, probably in 1952. I was then 11 or 12 years of age. Eventually, the name Students' Federation (SF) began to be used freely. Since then, I had been an activist of SF until I left Kerala in 1961. It is through SF that I became an activist of the Communist Party.

My activities as a student leader and communist bloomed after I joined the Kerala Varma College. The details of my activities during that period are not germane to the present volume. In India, 1950s was a decade of great hope and greater dreams. The ethos of the national movement still pervaded the atmosphere. That was a period of reconstruction of a land devastated by colonial exploitation for two centuries. That was a decade of the Non-aligned Movement and Afro-Asian solidarity expressed in the Bandung spirit. Jawaharlal Nehru strode the globe like a colossus. To be called a leftist or a communist was a badge of honour. The reform process of Kerala was in the final stages under the leadership of the Left. When communists came to power in Kerala in 1957, it was considered a triumph and celebration of Indian democracy. Most of my political activities were during that decade. The hopes and dreams of the 1950s have somewhat dimmed now, but they are the ones that moulded my character.

The 1950s, though vibrant, were not without doubts and confusion. Until the middle of the decade, the communist movement was a monolithic global enterprise, most of the time led by Joseph Stalin. The de-Stalinization articulated by Khrushchev in 1956, led to the demolition of many myths. The subsequent power struggles in the Soviet Union led one to believe that there was something rotten in Denmark. The schism between Soviet Union and China added to the confusion and dismay. The final blow then was the dispute between India and China, which began to surface towards the end of the decade. These occurrences led to serious reservations about the international communist movement.

The developments in Kerala were taking place so rapidly that there was no time to brood about this confusion. My hectic involvement with the Left movement was during 1958-1961 when I was in the late teens. The main centre of my activity was Thrissur. I also rose rapidly to the Kerala leadership of SF. I then had occasion to deal with the state leadership of the Left movement as well. That was a time when the movement was star studded and most of the intelligentsia was with the Left. The Left was perceived as the hope for the future. I have very pleasant memories of a large number of colleagues and leaders. My political guru was C. Janardanan, who was a member of the National Council of the undivided Communist Party and also a Member of Parliament for some time. At the higher level of leadership, the person with whom I had most interactions was C. Achutha Menon, who subsequently became a long serving and celebrated Chief Minister of Kerala. EMS, of course, was a constant presence in our consciousness. I also had strong interaction with the legendary mass leader and the first leader of the opposition group in Parliament, A.K. Gopalan. There were many other important people with whom I had close relationships. They included K.K. Warrier and P. Narayanan Nair, both veterans and Members of Parliament for extended periods; E. Gopalakrishna Menon, an effective leader and the gentlest politician I have come across; Joseph Mundassery, a doyen among Malayalam literary critics and Education Minister in the 1957 EMS Ministry; and V.V. Raghavan and K.P. Prabhakaran who were, among other things, Ministers in the Kerala Government on different occasions. A younger person with whom I worked closely was C.K. Chandrappan who later became a Member of Parliament twice and also led the (divided) Communist Party of India in Kerala, as its Secretary. When I left Kerala in 1961, he was the General Secretary of SF in Kerala and I, one of the four Secretaries. The leaders then were a class apart. They justified Maxim Gorky's statement "Man! what a beautiful word!". They were simplicity personified. Their caliber was high and their character was unblemished. I still cherish my strong association with the leaders and the rank and file of the then Left movement of Kerala.

Even though I have had no direct interactions with him, a person who greatly influenced me was Jawaharlal Nehru. Another great man of that period, Nehru's guru Mahatma Gandhi impacted, and continues to impact, several generations. Albert Einstein said about Mahatma Gandhi: "Generations to come, it may be, will scarce believe that such a one as this ever in flesh and blood walked upon the earth". To me, the Mahatma was a distant luminous icon, a Godlike figure who deserved to be admired and listened to. However, I could not personally relate to him. On the contrary, I felt complete empathy with Nehru. He was all of flesh and blood, in spite of his greatness. I, like millions, could easily relate to him. I avidly read his Glimpses of World History, Autobiography and Discovery of India. His autobiography is perhaps the most exciting book that I have ever read. I have also read much else that he wrote and what was written about him. Naturally, one did not agree with everything that he said or did. I, like many others, was a stern critic of Nehru, when he was coerced into dismissing the EMS government in 1959. However, his failings were miniscule compared to his achievements and the service he rendered to the country and the world. He was truly the architect of modern India. He laid the foundation of secular democracy in India. He was also substantially responsible for laying the foundations of modern industry in the country with special reliance on heavy industry. It was largely thanks to his vision that independent India had a good infrastructure for scientific research and technological development. He laid great emphasis on scientific temper. He often referred to great manufacturing units and scientific institutions as temples of modern India. Many aspects of his national and international policies were also attractive for me. Of course, Nehru has to be judged in the context of the times in which he worked. Probably no one could have done better than him in the formative years of independent India. I have been, and continue to be, inspired by Jawaharlal Nehru and his ideas.

In spite of my intense preoccupation with political activities, I obtained a first class in the B.Sc. degree examination in 1960. Most of my leaders, notably Achutha Menon, wanted me to go for higher studies. I could not get admission to a M.Sc. degree course in Kerala in the first round. I was offered a seat in the second round. By then my plans had changed. I came to the conclusion that if I were to go for higher studies, it was better done outside Kerala. I felt that I may not be able to cope with pressures of higher studies and those of political activities simultaneously. In the meantime, I had promised Janardanan that I would continue my activities as student leader for one more year. Thus, my plans for higher studies were deferred until the middle of 1961.

In the meantime, rapid developments were taking place in the international communist movement and within the Communist Party of India. Among the communists of India, there have always been two different views on the relation with the Indian National Congress. One group advocated closer relationship while the other preferred total opposition. The inner party struggle between the two groups became intense by 1960. The dismissal of the EMS government through central intervention in 1959 added to the bitterness. Different perceptions of the schism in the international communist movement and conflict between India and China, also added to the chasm between the two groups. The compromise reached at the Vijayawada Congress of the Communist Party in 1961 was short lived.

Thus, I had mixed feelings when I left for Delhi in June 1961 in search of avenues for higher studies. On one hand, there were pleasant expectations of an academic career at a high level. On the other hand, I was despondent about the future of the communist movement. It is difficult to explain the devotion we had for the movement which, we believed, stood for the final emancipation of mankind. It was difficult to imagine a life except with a unified communist movement in the background. In Delhi, for a couple of months, I was taken care of by the set up associated with the Party headquarters and offices of various associated mass organizations. There were many who helped me to find a place for post graduate education. The most important among them was the late R.C. Poduwal, a former student of my father. The father of a colleague of his was a professor at Allahabad University. The best schools of Physics in India were then at Delhi University and Allahabad University. Competition for seats in Delhi University was intense. I was perfectly happy with Allahabad University, but I had no response from them. I then went to Allahabad to make enquiries. It then transpired that a decision was made to admit me to their M.Sc. course. However, the concerned clerk in the office did not send the intimation to me. He had another candidate who was in the waiting list. He thought that this candidate would gain admission if I did not join. However, he did not anticipate my physically appearing at Allahabad. I was then formally admitted to the M.Sc. course, I think in August 1961. I continued political activities at a low level at Allahabad. However, that was the weaning period partly because of the disillusionment arising out of the inner party struggle in the Communist Party. The activities at Allahabad practically came to an end when the India-China war erupted in late 1962.

2

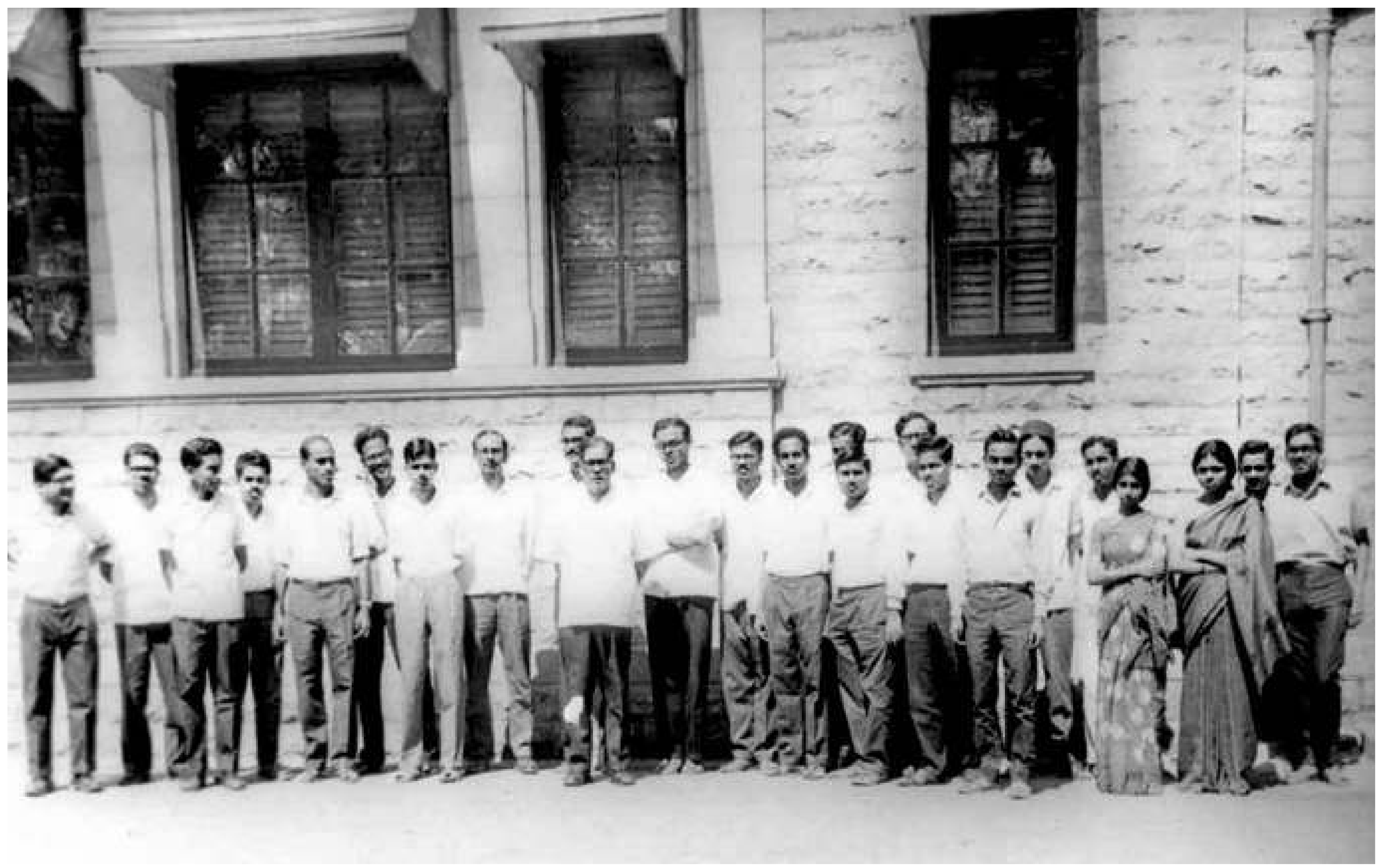
FOUNDATIONS OF FUTURE CAREER

Allahabad. A true student of science

The tempo of my life substantially changed at Allahabad. Freed from pressures of active public life, I almost became a normal twenty year old. Allahabad University was divided into two campuses. The main campus was at one end of a straight road. The other campus, called the Muir Central College, was smaller and was situated at the other end of the road, a few hundred metres away from the main campus. The smaller campus was exclusively meant for the departments in the Science Faculty. The tall tower in the Muir Central College is an important landmark of Allahabad. Sir Sunderlal hostel, in which I lived for two years, was situated between the two campuses, on one side of the road connecting them. That helped me to experience the vibrance of university life.

The hostel life was rich with many cultural events, discussion groups, etc. To start with, there was some ragging. I feigned total ignorance of Hindi and I substantially escaped it, as it was difficult for most seniors to rag in English! I was the sole resident from the South in the hostel. The workers in the hostel used to refer to me as Madrasi babu, a common term used for all from the South. When they realized that I resented being called so, they began to call me *pandrah* number babu. I, thus, more or less became *kaidi* number *pandrah*! It also took a little while to get used to new practices. Breakfast often consisted of jelebi, samosa, etc, brought in by a local vendor. One prepared tea or coffee in one's own room. There was no common mess in the hostel. Instead there were several *maharajs* (cooks) associated with the hostel. You could choose any one of them. On the whole, hostel life was enjoyable.

One of the things which many of us did in the evening was to go to Civil Lines, the fashionable quarter of Allahabad. The favoured mode of transport was cycle rickshaw. The cycle rickshaw ride from the university area to Civil



Research students of the Physics Department of the Indian Institute of Science in the mid 1960s. R.S. Krishnan is in the middle. Vijayan is next to him. Kalyani is second from right in the front row.

A few colleagues in the X-ray laboratory in mid 1960s.

Front row (L to R): Kalyani, H. Manohar, Shantha Venkataraman
Back row (L to R): M.A. Viswamitra, Vijayan, N.V. Mani

With C.V. Raman in the company of a few students of Mysore University. Vijayan is at the extreme right. Yathindra is at the extreme left.

Lines, I recall, costed six annas (approximately 35 paise). When I began to understand Hindi better, I also began to enjoy Hindi films. One of the early films that I remember vividly is “Hum dono” featuring Dev Anand, Sadhana and Nanda. I recall that the film opens with a heady duet involving Dev Anand and Sadhana. Unlike in Kerala, cricket was a rage at Allahabad and I got interested in following the game. That the main university cricket ground was in the Muir Central College, also helped. Naturally, I had many friends. They included Raj Bahadur Singh who subsequently worked in the National Thermal Power Corporation; Ramji Srivastava who was the Head of the Physics Department of Sardar Patel University, Anand; S. Rajagopalan who headed the Physics Department of the Nagpur University and Ram Prakash Singh who worked at IIT Kharagpur and also was the Vice-Chancellor of Lucknow University.

Although my primary association was with the Physics Department of the Science Faculty, I had some familiarity with the activities of the main campus as well. Many luminaries taught at the Allahabad University. For example, Firaq Gorakhpuri, the great Urdu poet, taught in the English department. Incidentally, he was a Hindu and Firaq Gorakhpuri was his pen name. Harivansh Rai Bachchan, the well-known Hindi poet and father of Amitabh Bachchan, also taught English at the University. Among other things, these two poets demonstrated that literary talent in an Indian language and proficiency in English, are not mutually exclusive. Many important lectures used to take place in the main campus. The lectures I listened to during that period included those of Jawaharlal Nehru and V.K. Krishna Menon.

Allahabad was, and still is, a cultural centre of Uttar Pradesh, and to an extent, India. The famous Triveni Sangam, the site of Kumbh Mela, was only a few kilometers away from the University. Swaraj Bhavan and Anand Bhavan, the abodes of the Nehrus, were also in the neighbourhood. The Allahabad ambience was rich in Indian culture and the history of the national movement. The history of Allahabad is studded with names of great leaders. My stay in Allahabad, though short, enriched me. I now feel perfectly at home in the North Indian ambience, particularly the ambience of Uttar Pradesh.

The Department of Physics at Allahabad University has had a long and distinguished history. Those who headed the department in the past included Meghnad Saha, K.S. Krishnan and K. Banerjee. Alumni of the department have occupied important positions in different parts of India. By the time I joined the department as an M.Sc. student, the old glory had begun to fade. However, some of that still pervaded the atmosphere of the department. Most of the teachers were active researchers as well. There was considerable respect for excellence and scholarship. I took to the M.Sc. course like fish to water. I had some difficulty in the initial stages because my Mathematics was somewhat weak. In my B.Sc. course, I studied Physics as the main subject and Mathematics as the subsidiary subject. In most North Indian universities, these subjects were taught with equal importance. Therefore, my proficiency in Mathematics was less than that of most others. Once I overcame this deficiency through extra reading, I began to enjoy my studies.

I performed rather well in my M.Sc. (previous) examination. There were three choices for the elective subject in the second year. They were Electronics, X-rays and Spectroscopy. Traditionally, students with top marks chose Electronics. However, I preferred X-rays. Somehow I felt that X-rays enabled one to dwell deep into matter. That choice turned out to be the correct one, as it laid the foundations of my career as an X-ray crystallographer. Incidentally, it was when I was an M.Sc. student at Allahabad that Max Perutz and John Kendrew received the Nobel Prize for determination of the structures of haemoglobin and myoglobin, respectively, using X-ray crystallography. That was a landmark event in the history of structural biology, particularly macromolecular crystallography, the area in which I was subsequently deeply involved. I vividly recall S.K. Joshi mentioning about the Nobel Prize in the X-ray class. My recollection is that I completed the M.Sc. course in 1963 with the third rank in the university. The first was S.K. Mohanty who settled abroad, and the second was Susheel Tripathi, who joined the Civil Service and retired as a Secretary to the Government of India.

The teachers who taught me at Allahabad included Rajendra Singh who subsequently rose to become the Head of R.S.S., Murli Manohar Joshi and Sri Krishna Joshi. I did not have much to do with Rajendra Singh after I left Allahabad. I continued to be close to the other two. I always deeply appreciated M.M. Joshi's concern and affection for me. The teacher who influenced me most was S.K. Joshi. He was a lecturer, simultaneously pursuing his Ph.D. programme. Even then colleagues had marked him out for his brilliance. Initially I had some communication problem with him. His *pahadi* English and my Malayalam English were orthogonal! I overcame this difficulty very quickly; I guess his *pahadi* accent and my Malayalam accent, when speaking English, got tempered over the years. In my career immediately after completing my M.Sc. course, I relied greatly on his advice. Years later, I had occasions to interact with him in different capacities. Joshiji, of course, served Indian science in many different ways, including as the Director General of the Council of Scientific and Industrial Research (CSIR) and President of Indian National Science Academy (INSA).

I was still involved in political organizational work with low intensity at Allahabad. I also used to follow the internal quarrels in the Communist Party, which greatly depressed me. These quarrels began to approach a breaking point after the open war between India and China in late 1962. Slowly, disillusion was creeping into my mind. On the other hand, science began to excite me more and more. It was at Allahabad that I truly got interested in science. That was where I decided to choose scientific research as my future career.

At Indian Institute of Science as a research student, R.S. Krishnan and others

After completing the M.Sc. course, I sought the advice of S.K. Joshi regarding my future career. In fact, I wanted to work with him for my Ph.D. degree. He dissuaded me from doing so. He suggested three possible options for me to pursue. One was with Ajit Ram Verma at the Banaras Hindu University. Another choice was G.N. Ramachandran (GNR) at the Madras University. He also gave introductory letters to A.R. Verma and GNR. Yet another place he suggested was Indian Institute of Science, Bengaluru (then Bangalore). Before I left Allahabad for home, I travelled to Varanasi to meet A.R. Verma. At that time, he was away from BHU which I did not know (those were pre-mobile and, to an extent, pre-telephone times!). I left the introduction letter in his office and returned home.

After coming home to Kerala, I contacted GNR at the Madras University and met him there. That was the time when he was at the peak of his scientific productivity. During our conversation, he asked me some scientific questions for which I provided reasonable answers. He told me that he was happy with me and would let me know his decision after consulting the university authorities, as I was not a student of the Madras University. In the meantime, I realized that the Head of Department of Physics at the Indian Institute of Science, R.S. Krishnan, hailed form Rappal, a village a few kilometers away from our home at Cherpu. My father and I met R.S. Krishnan during a visit of his to Rappal. After examining my credentials, he agreed to consider my application, provided I cleared an interview with him and his faculty colleagues in the department. I appeared for the interview on the appointed day. The interview went well. The only thing that I insisted was that I should be allowed to work in X-ray crystallography. The interview board was agreeable to that and I was offered admission as a Ph.D. student in the Physics Department of the Indian Institute of Science.

The moment I took my first hesitant steps into the Institute, I was sure that this was the place I wanted to work in. Before I formally joined the Institute, I was offered admission to work with A.R. Verma and GNR as well. However, I stuck to my decision to join the Institute, a decision I never regretted. It is another matter that I subsequently became a close colleague and, to an extent, a successor of GNR. I also grew close to A.R. Verma.

I continued to be formally, though tenuously, associated with the Communist Party, even after joining the Institute in 1963. Then the unthinkable happened in early 1964. The Communist Party split into two that year. Many of us felt that one of the bases of our life had been knocked off. It took me several years to recover from this blow and develop a new approach to public life. In any case, my political life came to an end in 1964. Since then, I have never been associated with any political party. I plunged whole heartedly into scientific research.

The Physics Department of the Indian Institute of Science was established by C.V. Raman in 1933 and was therefore a thriving centre of high class research. On his retirement in 1948, his former student R.S. Krishnan became the head of the department. When I joined the department as a research student in 1963, Krishnan was at the peak of his prowess and the department was almost synonymous with him. Born in central Kerala, he took his B.A. (Hons.) degree from St. Joseph's College, Trichy in 1933. He joined C.V. Raman for research and obtained his D.Sc. degree in 1938. He then worked in nuclear physics at the Cavendish Laboratory at Cambridge with the Nobel Laureate John Cockcroft for three years and obtained a Ph.D. degree in 1941. The intention was to start work in nuclear physics at Bengaluru. However, he was subsequently prevented from doing so as it was decided that research in the area would be carried out only under the aegis of the atomic energy establishment. Krishnan was naturally bitter about it. He continued to work in spectroscopy and solid state physics. His performance in these areas was outstanding.

In spite of his outstanding performance, Krishnan did not receive the recognition he deserved. Part of the reason for this was his getting caught up in the controversy between Raman and Max Born. Max Born was one of the founders of quantum mechanics. During the Nazi regime in Germany and elsewhere, he became a refugee. Raman brought him to Bengaluru and he worked for a period in the Physics Department. Subsequently, he moved back to the West. In the meantime, a major controversy erupted between Raman and Born in relation to lattice vibrations. It eventually turned out that what Raman advocated was a special case of Born's approach. Raman was unhappy that Krishnan's results appeared to favour the approach of Born. Raman could sometimes be unreasonable. Max Born decided to nominate Krishnan for the Fellowship of the Royal Society. He approached Raman to be the seconder. Raman felt insulted. He appears to have said that Krishnan was his student and if Born proposed, he would oppose the proposal. I had heard this story before, but I believed it only when Krishnan himself told this to me during the last stages of his life. I am not aware of Krishnan having hurt anybody seriously, but he could be undiplomatic in his pronouncements. For all these reasons, Krishnan did not reach the heights he deserved in peer recognition. I had excellent relations with him. He was a father figure to me. Our close relationship extended to his family as well.

In addition to R.S. Krishnan, who towered above everyone else in the department, the faculty members then included P.S. Narayanan, G. Suryan and V.S. Venkatasubramanian as Assistant Professors and M.A. Viswamitra as lecturer. While I was a student, E.S. Rajagopal joined as an Assistant Professor and R. Srinivasan as a lecturer.

X-ray crystallography

As I indicated earlier, the topic of my research was X-ray crystallography. X-ray crystallography is the most important method for exploring the atomic and molecular structure of matter. X-ray diffraction was discovered in 1912 by von Laue and his colleagues at Munich. The subsequent early development of the area took place in England under the leadership of William Bragg and his son Lawrence Bragg. The first crystal structure to be elucidated was that of sodium chloride in 1913. That marked the birth of X-ray crystallography. Laue and the Braggs were awarded the Nobel Prize. When Lawrence Bragg got the Nobel Prize in 1915, he was at 25 years, the youngest person to get a Nobel Prize in science. Since then, X-ray crystallography, in addition to being a technique, grew into a structural science. There is a story, perhaps apocryphal, associated with Lawrence Bragg. Apparently, he was courting a young lady at that time. When he finally proposed to her, he mentioned that he happens to have a Nobel Prize as well! The future Lady Bragg was apparently suitably impressed!

The impact of crystallography has been far reaching and over the decades, dozens of crystallographers have been awarded the Nobel Prize. The years 2012 and 2013 were celebrated the world over as centenaries of the discovery of X-ray diffraction and the birth of X-ray crystallography, respectively. In view of the importance of the area, the U.N. declared 2014 as the year of crystallography.

For those who are not familiar with the subject, a brief outline of X-ray crystallography is perhaps in order. X-rays were discovered in 1895 by Roentgen. Subsequently, it was established that they are part of the electromagnetic spectrum, like visible light, microwave, radio waves, etc. Waves in the wavelength range of 0.1 to 10 nanometres (nm) are usually referred to as X-rays. Ordinary light has a wavelength of about 600 nm. Thus, X-rays have about a 1000 times the penetration power of ordinary light. This is what enables us to examine internal organs in the body using X-rays. Light originates on account of transitions of the outermost electrons of atoms while transitions of inner electrons lead to X-rays.

Except in a few substances like glasses, particles, which could be atoms, molecules or their collections, exist in a periodic fashion in solids. In a metal, the particles would be atoms. In a salt, say sodium chloride, the repeating unit would be a collection of positive and negative ions. In an organic crystal, a molecule or a collection of molecules would constitute the repeating unit. Thus in general, translational periodicity is a fundamental property of matter in the solid state. In principle, any pure substance can be crystallized. In a crystal, depending upon the substance, the distance between two neighbouring particles, which is called periodicity, varies from about 0.5 nm to several nm. The periodicity of crystals is similar in magnitude to the wavelength of X-rays. Therefore, crystals can function as three dimensional gratings for diffracting X-rays.

When X-rays are incident on a crystal, the diffraction pattern would consist of a large number of X-ray beams. The number of such diffracted beams could vary between a few 100's to several 1000's depending upon the complexity of the particle constituting the crystal. There are several ways of recording these beams. Laue originally used photography for recording the pattern. Therefore, one often uses the term diffraction spot. The Braggs used ionization chambers to record diffraction patterns. Subsequently, photographic techniques again became popular only to yield to electronic measurements after a few decades. The popular mode of modern data collection involves sophisticated position sensitive detectors. The method of producing X-rays also underwent changes over the decades. However, the basic principles of X-ray crystallography remain the same and simple in principle (but not in practice!). The disposition of the beams in the diffraction pattern provides information on the arrangement of particles in the crystals, while the intensities themselves form the data for determining the internal structure of the particle which, as mentioned earlier, could be a collection of atoms or ions, a molecule or a collection of a few molecules.

The early efforts in crystallography were largely on inorganic substances. Subsequently, organic substances came under the scanner of crystallographers. Both these efforts led to revolutionary changes in the understanding of the structure of matter. The peak of the glory of organic crystallography was the determination of the structure of vitamin B12 by Dorothy Hodgkin. This structure analysis is often described as one which liberated organic chemists from the drudgery of structure analysis. The structure of DNA was determined by Francis Crick and Jim Watson, partly using the X-ray diffraction results provided by Wilkins and Rosalind in a Nobel Prize winning effort. The first crystallographic determination of protein structures were those of myoglobin and haemoglobin by the groups of John Kendrew and Max Perutz, respectively. They were awarded the Nobel Prize for this effort in 1962. Dorothy Hodgkin was awarded the Prize in 1964 for the work on vitamin B12. It was during this period of excitement and hope that I started my research in crystallography.

In the X-ray group of the Physics Department

C.V. Raman did outstanding work on crystals, but was not a crystallographer in the conventional sense. It was his student K. Banerjee who initiated structural crystallographic studies in India in the 1930s at the Indian Association for the Cultivation of Science in Kolkata (then Calcutta). In the Physics Department of the Institute, crystallographic studies were established by G.N. Ramachandran and his younger colleague Gopinath Kartha in the late 1940s and early 1950s. After they left for Chennai (then Madras) in 1952, X-ray work in the department was carried out by S. Ramaseshan and his students till 1962 when he moved to IIT Madras. Both Ramachandran and Ramaseshan were students of C.V. Raman. On the departure of Ramaseshan, M.A. Viswamitra, a student of Ramaseshan, took over the reins of the X-ray lab in the department. When I joined him as a student, he was very young and had not even completed the customary post-doctoral stint abroad.

Apart from Viswamitra, the seniormost member of the X-ray group was Shantha Venkataraman, a former student of C.V. Raman and R.S. Krishnan, who was resuming her career after raising a family. She subsequently was in the Physics Department of the Mysore University. H. Manohar had just completed his Ph.D. under the supervision of S. Ramaseshan. Subsequently, he moved to the Department of Inorganic and Physical Chemistry to start an X-ray group there. S.N. Vaidya who was earlier a student of Ramaseshan was in the final stages of his doctoral work. Subsequently he worked in the Bhabha Atomic Research Centre in Mumbai (then Bombay). Another student, just senior to me, was K.K. Kannan with whom I had many interactions in my subsequent career. Junior to me was Kalyani. Two more junior students were J.K. Mohan Rao and K. Jayalakshmi, both of whom are now in the United States. N.V. Mani, a contemporary of Viswamitra, was in the group for some time. He subsequently returned to U.S. where he died prematurely.

Those who joined the Ph.D. programme along with me in the Physics Department included S.R. Uttarwar and S. Devanarayanan. The former died comparatively early, after occupying leadership positions in Keltron, Electronic Research and Development Centre and the Software Technology Park, all at Thiruvananthapuram. Devanarayanan worked as a Professor in the Kerala University. My other friends in the department included K.R.K. Easwaran, T.R.S. Reddy, R.S. Katiyar, Surendra Pal, G. Rangarajan, A.V.R. Warrier, A.J. Michael and many others. Social life at the Institute was also rich and I had friends belonging to many other departments. Among them, one with whom I had many interactions subsequently, was K.P. Gopinathan.

Many anecdotes from that period come to my mind. One was connected with a visit of Allen Mackay of Birkbeck College, London in 1964. A visit of his to the Raman Research Institute to meet C.V. Raman was arranged. It was suggested that a couple of students could also accompany Mackay. It was felt that Raman might get upset if the number was large. I was then the juniormost student in the group and was therefore asked to stay back. Vaidya and Kannan accompanied Mackay. I was, of course, sorely disappointed. However, within an hour, Vaidya and Kannan were back in the lab, sans Mackay. Apparently, Raman asked whether they were Mackay's students. When he replied that they were students of the Indian Institute of Science, Raman got upset. He had a love-hate relationship with the Institute. At that point of time, the hate component predominated. According to Kannan, Raman told them "Run away. You know what I mean, run away"

After the above incident, I could not muster courage to meet Raman as a student of the Institute. Not long afterwards, I met him in a group pretending to be a student of the Mysore University. Shantha Venkataraman had brought a group of M.Sc. students from Mysore to visit the Raman Institute and meet Raman. She told me that I can join the group, which I did. The great scientist spent a couple of hours with the group with great enthusiasm. He personally took us around the Raman Institute museum and explained the significance of every item in it. We were all charmed and overwhelmed by his consideration for us. The group included N. Yathindra who subsequently led the Department of Crystallography and Biophysics at the Madras University and the Institute of Bioinformatics and Applied Biotechnology in Bengaluru. I met Raman a couple of times more, when I escorted distinguished overseas visitors to the Raman Institute. In addition, on one occasion, Raman barged unannounced into the lecture hall of the Physics Department of the Institute. The lecturer of course gave way to Raman. The latter proceeded to examine the eyes of everyone present and discovered that a couple of them were color blind! He was then engaged with the subject of vision.

My Ph.D. programme was concerned with metal complexes of antipyrine, an analgesic which is no longer in use. The material was supplied by C.C. Patel of the Department of Inorganic and Physical Chemistry. The programme was well set before Viswamitra left for Oxford in late 1965 to work with Dorothy Hodgkin as a post-doctoral fellow. Since then, I was on my own. Furthermore, as the seniormost member of the group, I also assumed the responsibility for the lab. It is during this time that I got involved in supervising the work of Kalyani who worked on organic compounds supplied by M.V. Bhat of the Department of Organic Chemistry. In between, I also worked on the structure of a ferro-electric substance. I submitted my Ph.D. thesis in late 1966, but continued in the department till the very end of 1967.

X-ray crystallography then did not involve the use of many sophisticated pieces of equipment. X-ray generators were primitive by present day standards. They were looked after by students themselves. The instrument for collecting diffraction data was the Weissenberg camera. It took several months to collect data from one crystal. Intensities on X-ray films were manually estimated using calibrated strips. Dark room was an integral part of the X-ray lab. The films on which X-ray data were recorded on Weissenberg cameras were developed and fixed by students themselves. The enormous calculations involved in structure analysis were carried out manually, using special techniques developed for the purpose (for example, Beevers-Lipson strips). Mechanical calculating machines were widely used. An electrical calculating machine was a proud possession. On account of limitations in computing power, most of the work was carried out in two dimensional projections. Three-dimensional analysis commenced only with the advent of digital electronic computers.

The transition from manual calculation to electronic computation took place while I was a Ph.D. student. Probably, the first digital computer to be commissioned in Bengaluru was Elliott 803 at Hindustan Aeronautics Ltd. (then Hindustan Aircraft Ltd., HAL). The computer filled a medium sized room. The total memory of the computer was 4096 words (I do not remember whether the words were 4 byte long or 6 byte long). The same was true about the Ferranti Sirius computer at the National Aerospace Laboratories (then National Aeronautical Laboratory, NAL), which we started using subsequently. The input and output were through five-hole paper tapes. Each set of calculations normally took several hours. The most powerful computer in India then was at the Tata Institute of Fundamental Research (TIFR), Mumbai. The machine was called CDC-3600. In that machine, punched cards were used as input-output media, instead of paper tapes. We have used that computer as well. Since then, I have had occasion to use computers of almost every successive generation.

The most important centre of crystallography and molecular biophysics (now called structural biology) in India, those days was the department in Madras University which GNR founded and nurtured. Although I did not join him as a student and preferred the Indian Institute of Science for my Ph.D. programme, I had unbounded admiration for him and the department. GNR was not only a great scientist, but also an organizer of scientific events (but not routine administration). One of the events he started was the annual national seminars on crystallography. The first of these was held in February 1964. That was when I met for the first time many crystallographers of India, including S. Ramaseshan. The participants in the seminar included Academician Belov and his former student Simanov. That was the beginning of my long association with the Madras department. Until I left Bengaluru for Oxford in 1968, the national seminars at the Madras University were important events in my academic calendar. The seminars were subsequently taken over by the National Committee for IUCr, of the Indian National Science Academy and much later by the Indian Crystallography Association.

The first major international conference I participated in was again the one organized by GNR in Chennai in January 1967. The distinguished chief guests at the conference were Linus Pauling and Dorothy Hodgkin. Both of them were iconic figures, but they presented a study in contrast. Linus Pauling had a personality which dominated everything and everybody around him. He was a forceful orator and filled the stage whenever he spoke. Dorothy, on the contrary, had a self-effacing personality. She made her presence felt by her humility and unobstrusiveness. It was at the 1967 conference that I first met Dorothy. Many other distinguished scientists participated in the meeting. But the person I remember the most is Gopinatha Kartha whom I was meeting for the first time. Kartha, a former associate of GNR, carried out the first determination of the three dimensional structure of a protein (Ribonuclease A) in the United States, working in Buffalo. I subsequently had a very close relationship with him until he passed away decades later.

The atmosphere of the Institute was vibrant with science, as it is today. Well known scientists from all over the world used to visit the Institute and we never felt that we were away from the centre of things. I particularly remember the visit of Lawrence Bragg, the ***Bhishma Pithamaha*** of X-ray crystallography, to the Institute while I was a student. Those who visited the Madras department also used to make it a point to visit the Institute and an interesting byline of these visits had to do with prohibition which was then in force in the Madras State (now Tamil Nadu). Many western scientists who came to Bengaluru after spending time in Chennai, used to be thirsty! I used to do the needful, but never drank alcohol until I left the shores of India for the first time. This trivial digression apart, the students of the Institute, certainly myself, felt very much part of the international scientific community, by the time we completed our Ph.D. programme.

3

OXFORD. DOROTHY HODGKIN, INSULIN AND MUCH ELSE

By the time I met Dorothy in Chennai in early 1967, she had read my Ph.D. thesis as an external examiner. She also knew about me as at that time, Viswamitra was a post-doctoral fellow in her laboratory. When she visited Bengaluru after the Chennai meeting, I was her main host at the Institute as I was then looking after the X-ray laboratory as the seniormost student in the group. Therefore, I had occasions to talk to her at length. Before she left Bengaluru, she offered to take me in her laboratory. Needless to say, I was overjoyed.

Insulin in the early history of protein structure

In those days, there were two groups working in Dorothy's laboratory. One was concerned with the structure analysis of comparatively small molecules like vitamin B12 and penicillin. The other group was engaged in reviving the work on insulin which was initiated by her in the 1930s and was on the back burner for decades. Dorothy left the decision to me as to which group I should join. All my well-wishers advised me to join the small molecules group. Work on insulin had not till then produced any definitive result. Therefore, it was risky to join the insulin group as I was expected to remain in Oxford only for a couple of years. However, probably on account of the recklessness of youth, I chose to join the insulin group. Subsequently, that decision turned out to be very fortunate.

The protein hormone insulin is part of the history of macromolecular crystallography and biochemistry. It was J.D. Bernal who initiated work on macromolecular crystallography at Cambridge. He was a physicist with special training in X-ray crystallography. However, his interest

Vijayan met Dorothy Hodgkin for the first time in Chennai in 1967

In front of S. Ramaseshan's home in Bengaluru in 1967. Vijayan is behind Dorothy and Kalyani is on the left. Ramaseshan is third from right in the back row. Kausalya Ramaseshan is with baby Tara.

At Oxford party. Thomas Hodgkin and Vijayan are sitting on the ground. Tom Bundell is right behind Vijayan.
(L to R) : David Philips, Dorothy, A.C.T. North, Ted Baker and Eleanor Dodson

Dorothy and Vijayan during shopping

was not confined to a single area. He has made outstanding contributions in widely different areas of science. He was a committed communist. He has also written extensively on the history and social relevance of science. When the Second World War started, he immersed himself in the war efforts of Britain against Fascism and Nazism. It is said that Sir Winston Churchill was asked how he can take the help of a communist like Bernal in war efforts. He is reported to have replied that he would ally even with Satan to defeat Hitler! He got deeply involved in peace movements after the war. I, as a teenager, first heard about J.D. Bernal as a leader of the world peace movement. At that time, I never thought that I would eventually become an academic descendant of Bernal. On account of his deep involvement in war efforts, the peace movement and other societal issues, he could not complete many of the projects he initiated. He distributed his projects amongst his students and colleagues. Many of them rose to great heights and were widely recognized including the Nobel Prizes. He was a giant among the intellectuals of the 20th century. He was known as 'Sage' amongst his friends and colleagues. In the 1930s he was at Cambridge. Subsequently, he moved to Birkbeck College in London.

In the early 1930s, Dorothy Crowfoot (it was after marriage that she became a Hodgkin) was a student of Somerville College at Oxford. This is the college in which many well-known persons like Indira Gandhi and Benazir Bhutto lived and studied. Dorothy took her B.A. degree in Chemistry. It involved doing research in the final year. This, she did in chemical crystallography. She was enamoured by the subject and she decided to choose a career in crystallography. Almost as a natural extension of this decision, she started her Ph.D. research at Cambridge under the supervision of J.D. Bernal.

Several hypotheses then existed about the structure of proteins. It was also known that proteins can be crystallized. Determining the structures of those crystals was then even beyond imagination. During that period, a colleague of Bernal happened to visit Uppsala which was then the capital of biochemistry. In the Uppsala laboratory, a scientist had stored the solution of a pure protein in a test tube in the fridge and had gone for a skii holiday. On his return, to his utter surprise, he found the test tube full of crystals. Normally, it is very difficult to crystallize proteins. The story has it that many people subsequently stored proteins in the fridge and went on a skii holiday, as a method of crystallization! But it never worked again. Coming back to our story, Bernal's colleague told the Uppsala biochemist that he knew a scientist in Cambridge who would be willing to give his eyes to get hold of these crystals. The biochemist spared some protein solution containing crystals. The colleague brought the test tube containing crystals in his pocket and handed over it to Bernal. The crystals were those of the digestive enzyme pepsin.

Bernal and his student Dorothy recorded the X-ray diffraction pattern from pepsin crystals and the results were published in the journal *Nature* in 1934. That marked the beginning of macromolecular crystallography. An overwhelming majority of thousands of macromolecular crystallographers in the world today, are descendants of Bernal and Dorothy. After completing her Ph.D. work at Cambridge, she returned to Oxford as an independent researcher. The first problem she took up was the X-ray study of insulin crystals. The results of this preliminary effort were published in *Nature* in 1935 when Dorothy was 25 years of age. She reckons the 1935 work on insulin as the most exciting event in her life. The second most exciting event was the solution of the three-dimensional structure of insulin in 1969, 34 years later. Preliminary X-ray studies on a few more proteins were carried out in the 1930s under the guidance of Bernal and Dorothy at Cambridge and Oxford, respectively. The progress of the work was interrupted by the Second World War. In any case, the technological armoury of crystallography then was not equal to the challenges involved in detailed structural studies of proteins. It was only around 1960 that the structures of myoglobin and haemoglobin were determined by the groups of John Kendrew and Max Perutz, respectively.

Although the work on insulin was initiated in 1935, it was on comparatively small biomolecules that she concentrated her attention in the next couple of decades. She carried out, alone and in collaboration with Bernal, path-breaking investigations on steroids. During the Second World War, there was a great demand for penicillin. Penicillin could not be synthesized as its molecular structure was not known. Efforts by chemists to determine the structure of this important antibiotic failed. Finally, Dorothy and her colleagues determined the structure of penicillin using X-ray crystallography. The structure turned out to be very different from those anticipated by chemists. Subsequently, she determined the structures of many other biomolecules, the most important of which was vitamin B12. She was awarded the Nobel Prize in 1964 for the structure determination of vitamin B12, almost exclusively using X-ray crystallography. In terms of sheer intellectual brilliance, probably no other structure determination can rival that of vitamin B12.

Insulin, a New beginning

Although, Dorothy made many outstanding contributions in the intervening decades and received a Nobel Prize in the bargain, insulin continued to be the molecule closest to her heart. In the light of the great progress in the methodology of crystallography in the 1950s, she resumed the work on insulin. It is interesting to recall that her last significant publication on insulin in the early years was in 1939. The subsequent important publication on insulin appeared only in 1966. That insulin continued to engage her attention, in spite of nearly three decades without results, is a measure of her perseverance. In the meantime, Fred Sanger elucidated the amino acid sequence of insulin for which he was awarded the

Nobel Prize. It is another story that he received a second Nobel Prize, decades later, for determining the sequence of nucleic acids. The determination of the amino acid sequence of insulin was also an added encouragement for Dorothy to resume her work on insulin. For some special technical reasons, structure solution of insulin using X-ray crystallography continued to be very difficult. By the middle of the 1960s, some encouraging signs began to appear. However, even those were not good enough to achieve structure solution. It was to this atmosphere, which was marked by hope and despondency in equal measure, that I entered the insulin lab in early 1968.

Warm relationships in cold England

I started from Bengaluru via Mumbai for London on January 6, 1968. Those were pre-jumbo days and one could not fly directly from Mumbai to London. Therefore, there were stops at Cairo and Rome before touching down in London on the 7th. The world was not then as globalised as it is today. Thus although I had interacted closely with a number of scientists from the West, the overall ambience in London appeared somewhat strange to me. The winter cold added to the strangeness. I was received at the airport by our old family friend, M.G. Ramakrishna Menon. Among other things, he founded a hydrogenation factory in Kozhikode during the late 1950s. He and his family migrated to UK in the early 1960s. I stayed with them for a couple of days in London before proceeding to Oxford. Subsequently, I and later my family, stayed with them whenever we were in London.

The day before I started for Oxford, it had snowed heavily in England. It was to a snow-bound London that I stepped out of the house that morning. I was seeing snow for the first time. Menon dropped me at the Paddington railway station in the morning. It was only after he left, I realized that most of the train services had been cancelled on account of snow. I spent several hours in the strange and extremely cold atmosphere. The train services were resumed in the afternoon. I then travelled to Oxford, dragging and carrying heavy suitcases and with a change of train at Didcot. It was dark by the time I reached the Oxford railway station by about 5 pm. I hired a taxi and somehow managed to reach the laboratory. Happily, Viswamitra was waiting there to receive me. From there, we proceeded to his house by walk and bus. That I had a fall on the way in the snow covered road, did not add to my confidence. I breathed easy only after I reached the flat in Summertown House where Viswamitra, his wife Meera and son Sanjaya lived.

I took time to get acclimatized to the English weather. In addition to the extreme cold and occasional snow, the atmosphere was most of the time overcast with drizzle. I felt somewhat morose. It was when I went to Europe in March that my mood lifted. On that occasion, I woke up one morning in Munich railway station amidst abundant sunshine. The atmosphere was very cold, but the sunshine lifted the mood. Until

I shifted to Summertown House in July 1969 after marriage, extreme chill was my companion whenever I was outside the laboratory which was mercifully centrally heated. Till then I had been a paying guest with a family. The heater in my room and that in the bathroom worked like a slot machine. If you put a six pence coin in the slot, you would get six pence worth of heat!

Unlike in the surroundings, the atmosphere in the laboratory was very warm. This was not exclusively because of the central heating system. Dorothy and her colleagues have always been like members of a family. In addition to her extraordinary scientific eminence, Dorothy's personality was characterized by extreme simplicity and love for humanity. Her husband, Thomas Hodgkin, was a well-known historian and communist. Dorothy was not a communist, but was a staunch leftist. She took strong stands in favour of liberation struggles and against imperialist intervention. However, her intervention was always in such a way as not to antagonize individuals. She was almost universally admired and loved. That enabled her to bring together diverse people from different countries using primarily scientific research. Her research group has always been very cosmopolitan. She has been active in the world peace movement. At some stage, she was the President of Pugwash.

Our relationship with Dorothy was not confined to the laboratory. We often stayed with Dorothy and Thomas in their enormous country home in a village called Ilmington. There we mingled with their children, grandchildren and other relatives. The visitors at Ilmington included the famous, not so famous, revolutionaries and refugees. We often visited the Oxford flat of Dorothy and Thomas as well. Her style of work in the laboratory was similar to her behavior at home. She hardly ever gave firm instructions. She led by example and through what appeared to be mild suggestions and coaxing. Therefore, only rarely one felt tense in the laboratory. In terms of mentoring, she transformed everything into gold through her Midas touch.

When I joined the group, the seniormost members of the insulin team were Guy Dodson and Eleanor Dodson. They had been working with Dorothy on insulin from the early 1960s. Guy was from New Zealand and Eleanor from Australia. Margaret Adams, then a graduate student, left the lab on obtaining her doctorate degree a few months after I joined the lab. Ted (E.N.) Baker from New Zealand joined as a post-doctoral fellow in 1967, with initially special responsibility for installing and running the newly acquired 4-circle diffractometer. Tom Blundell, who took his doctorate from Oxford, also joined the group in the same year. I joined in January 1968. For a long time, the only true blooded British person in the insulin group was Tom! Ours was a very coherent group. I was a very frequent visitor to the home of Guy and Eleanor. I also often visited the homes of Ted and Heather Baker and Tom and Leslie Blundell.

We interacted closely with David Philips and his colleagues as well. In fact, Dorothy's insulin group was located in the Laboratory of Molecular Biophysics (LMB) headed by him. Originally, most of the protein crystallography work in UK was carried out at Cambridge. There was a move to start organized efforts in the area in Oxford as well. Dorothy was the natural choice for leading this effort. However, she did not want to get involved in administrative work. She also felt that at that time she was too old to initiate organizational activities. She was, among others, involved in transplanting the whole lysozyme group headed by David Philips from Royal Institution, London to Oxford. David subsequently exhibited great leadership qualities. He established LMB in Oxford in the early 1960s. Dorothy's insulin group then moved to LMB. Her small molecule crystallography group remained in the Chemical Crystallography Laboratory across the university museum. The other senior members of LMB included Tony (A.C.T.) North, Collin Blake and Raghupathy Sarma. Another colleague in our age group was Louise Johnson who much later succeeded David Philips.

An incident which is still fresh in my memory is about the dinner I had in the Dodson household, a couple of days after I joined the laboratory. Most of the other guests that night were New Zealanders and Australians. I still had difficulty in following different accents and I did not understand much of the conversation that was taking place. However, I kept laughing when everybody else laughed! After the dinner, Eleanor asked, "how many white and how many black?" I was not sure with which group I should identify myself. On balance I raised my hand when she said black. Only later I realized that she was asking how many took coffee with milk and how many without milk!

Another amusing incident which I recall had to do with alcohol. I was a strict teetotaller in India. I was somewhat naïve and had exaggerated notions as to what alcohol might do to you. During the initial days in Oxford, I saw the wife of a senior Indian colleague of mine sipping sherry with no apparent harm to herself. That to an extent dispelled my misgivings. Even then, I had no idea about the alcoholic content of different beverages. Soon afterwards, Dorothy and Thomas took many of us to a pub for drinks. All others had ordered one pint of beer each. I was careful and said that I would take only half a pint. In another party, under the aegis of Thomas, wine was being served. I then said "Thomas, I will have only half a pint"!

Structure solution of insulin, celebrations, visitors (including Margaret Thatcher)

Ours was a balanced team with complementary expertise. Our main attention then was on a crystal form of insulin called 2Zn insulin. We already had two heavy atom derivatives containing lead. Guy and Tom, among other things, were busy with preparing and analyzing more heavy atom derivatives. To start with, my main pre-occupation was collection of accurate intensity data for the application of what is called the anomalous dispersion method. In addition, I was also involved in the crystallographic analysis. Eleanor had the overall responsibility for computation. Although each of us had specific responsibilities, all of us together got involved in every aspect of the work, an experience that stood us in good stead in our subsequent careers.

By the end of 1968, everything appeared to fall in place. A low resolution electron density map calculated in the first half of 1969 provided a rough picture of the 2Zn insulin hexamer. Soon afterwards, with some hope and some trepidation, a 2.8Å resolution map was calculated. Computer graphics was still in the future. The map sections were contoured by hand and stuck to perspex sheets. The perspex sheets were then appropriately stacked above a light box. Dorothy often commandeered the help of wives of students and post-docs in the effort. One important item in the laboratory then was a beautiful playpen for toddlers to play in while their young mothers worked!

I cannot do better than quote from an old article I wrote in Current Science (*Curr. Sci.* **83**, 1598-1606, 2002) to describe the excitement during the few days we took to roughly interpret the map. I wrote "In 1969, the number of proteins with known three-dimensional structures could be counted on one's fingers. Therefore, the solution of a new protein structure was of considerable historical importance. Furthermore, no structure of a protein or peptide hormone was then known. In addition, the importance of the protein and Dorothy's long and deep involvement with the work, led peers to eagerly look forward to the structure solution of insulin. Therefore, it was with great excitement and anticipation that we went through the final stages of the preparation of the map. The day on which we finally stacked the map sections, Dorothy happened to be away from Oxford. Guy and I were the first to examine the map. Neither of us had had any experience in interpreting protein electron-density maps. However, we had no difficulty in recognising a stretch of helix in the map. That turned out to be the B_{10}-B_{19} a-helix. Starting with the helix, we could build a substantial part of the B-chain, although we made one major mistake. We mistook a tyrosine side chain for a stretch of peptide. The model building was done in an approximate manner. There were no means for "fitting" the model into the electron density. Essentially, one examined the electron density in bunches of stacked perspex sheets and built the model using Kendrew model bits in a frame placed next to the map.

"Dorothy returned to the lab next morning, examined the map, confirmed the correctness of much of the polypeptide chain Guy and I had constructed and corrected the mistake we had made. For the next few days, our almost exclusive occupation was the building of the model. The logistics was such that we had to be on our feet to do so. Along with us two youngsters, Dorothy stood hours on end, often with swollen feet. In parallel, we prepared several structural diagrams, by hand of course, using different kinds of templates. The first round of model building was completed by early August..... Dorothy and Guy left for US on the 6th to participate in the Crystallography Congress at Stonybrook. Tom was already in the US. Guy stayed on for the Biophysics Congress at Boston which started in late August. I joined him there". By then, Kalyani had joined me and we got married (more about it later). She accompanied me to the US.

A notable event during this period was the visit of Max Perutz. As soon as he learnt that the structure of insulin has been solved, he rushed to Oxford along with a few younger colleagues to congratulate Dorothy and the rest of us. Those who accompanied him included Tom Steitz, a future Nobel Laureate who was then a post-doc at Cambridge. When we all gathered together, Perutz made a few remarks in his characteristic style. That was the time when the British Government had introduced life peerages. He said that if he were offered a life peerage, he might be called Lord Haemoglobin. If John Kendrew were offered one, he could be called Lord Myoglobin. If Dorothy were offered one, they would not know what to call her: Dame Cholesterol, Dame Penicillin, Dame Vitamin B12 or Dame Insulin. Dorothy's cap was full of feathers of different kinds. It is another matter that neither Max Perutz nor Dorothy accepted peerages. Both of them were awarded Order of Merit (OM), roughly equivalent to the Bharat Ratna in India. Dorothy was the second woman to receive the OM. The first was Florence Nightingale.

After the travels, primarily associated with the IUCr Congress at Stonybrook and the IUPAB Congress at Boston, we all assembled in the laboratory in September, 1969. By then, the news about the structure solution of insulin had spread like wildfire. Although we were not quite ready for it, the first major structural paper on insulin was published in the centenary issue of *Nature* at the persistent request of the editor. We were busy with many programmes such as seminars in and outside Oxford, BBC interviews etc. On such occasions, Dorothy was very careful in mentioning the contributions of each one of us. Many people used to mention that none of her present colleagues in the insulin group was even born when she started insulin work in 1935!

Our subsequent efforts were temporarily disrupted on account of a move from our location. The final destination was the new zoology building which was not quite ready for occupation. As an interim measure, we moved to a cold, yet cosy building in South Parks Road, which was slated for demolition. It is in this building that we resumed our work which involved primarily model building employing what used to be called the Richards box which had a half silvered mirror on which the map and the model could be simultaneously reflected. The model building was still manual. In the meantime, Dan Mercola from the US joined the group as a post-doctoral fellow.

Even in normal times, many visitors used to come to Dorothy's laboratory. The number of visitors dramatically increased after the structure solution of insulin. One particular visit that I distinctly remember is that of Margaret Thatcher who was then the Education Secretary (Education Minister) of the UK in the Conservative Ministry of Heath. That was a time when the immigration of Indian origin citizens of UK from Kenya and Uganda was a live issue. There was some racist overtone also for the discussion on this issue. The Conservative Party was perceived to be unsympathetic to the immigrants. Our colleagues in the laboratory were generally Left oriented. They decided that I should explain the structure of insulin to Thatcher, partly because I had a brown face! I did so in the presence of Dorothy and other colleagues. Sometime along the line, Margaret Thatcher began to ask scientific questions which surprised me, coming as they did from a politician. It was not difficult to answer those questions to her satisfaction. After she left, I asked Dorothy how this politician could ask scientific questions. Dorothy replied that Margaret Thatcher was a former student of hers! Thatcher did her B.A. in Chemistry at Oxford. The final year of the course was devoted to research, which she did under the supervision of Dorothy. Margaret Thatcher held Dorothy in high esteem, but I am not sure that she subscribed to Dorothy's political and social positions! Nor do I think Dorothy entirely approved of Thatcher's policies.

Despite distractions, we were concentrating in the lab on building as accurate a model as possible of 2Zn insulin, to replace the somewhat inaccurate model hurriedly published in the centenary issue of *Nature* in 1969. By the close of 1970, John and Sue Cutfield from New Zealand joined the group. The new corrected structure of insulin (2Zn insulin) was published, again in *Nature*, in 1971. That marked the end of an important phase, probably the most important phase, in the history of insulin crystallography.

1976-77 Stint in Oxford and further work on insulin

In the meantime, much else happened in the structure analysis of insulin. Liang Dong Cai from China had joined Dorothy's group in 1965, with the avowed intention of gaining experience in protein crystallography, for initiating work in the area in China. His stay was cut short and he was called back to Beijing when the Cultural Revolution gained momentum in China. However, he quietly continued to work on insulin at the Institute of Biophysics in Beijing. That was part of a well-orchestrated overall programme on insulin in China. This programme was supported and protected at the highest level even during the heydays of Cultural Revolution. The Beijing group independently determined the insulin structure in the early 70s and subsequently refined it. It was a measure of Dorothy's generosity that she encouraged the insulin group in Beijing in their efforts. In the meantime, another group led by Noriyoshi and Kiwako Sakabe at Nagoya, Japan had also started working on the crystallography of insulin. Eventually, they got in touch with Dorothy and worked partly in collaboration with the Oxford group.

In Oxford itself, investigations were carried out on other forms of insulin, particularly a crystal form called 4Zn insulin. On the original form, 2Zn insulin, the effort was to refine the structure at the highest possible resolution. Insulin was among the earliest protein structures to be formally refined crystallographically. The refinement of protein structures is bedeviled by many technical problems and the refinement of insulin structure amounted to a learning experience. The structure was refined at 1.5Å resolution in Oxford and York by Guy Dodson, Eleanor Dodson and others using difference Fourier synthesis. In parallel, the structure was refined by R. Agarwal and Neil Isaacs at IBM Research Center, New York employing least squares. The results of both the refinements were ready by 1976 and were expected to be the same. It was at that stage, that I joined Dorothy again for a year as a visitor.

My efforts in Oxford during 1976-77 were not chronologically contiguous with those during 1968-71. However, the former were essentially a continuation of the latter. Dorothy was due to formally retire at the age of 67 in 1977. She wanted one of her former associates to help her wind up much of the insulin work. An important element of personal generosity and concern appears to have also involved in her invitation to me to spend a year at Oxford. Essentially, Dorothy and I were the only fulltime members of the laboratory and I got to know her more than ever before. Both of us had personal distractions. Thomas was very ill and Dorothy had to look after him. Kalyani was pregnant and delivered a baby in May. In spite of distractions, the work went on well.

My mandate during 1976-77 was to combine the results of the two independent sets of refinement and prepare a paper. However, to our surprise and dismay, there were significant differences between the two sets of results. Most of the time during that year was spent in reconciling the results and developing approaches for the proper refinement of protein structures.

Much of this effort was completed by the time Dorothy formally retired in 1977, but she continued to be engaged with the finer details of the structure, mainly in association with Guy and Eleanor at York. I remember her carrying the insulin maps on a subsequent visit to Bengaluru and our working on them. Eventually, a final detailed paper on insulin was published in 1988, which covered an entire issue of the Philosophical Transactions of the Royal Society. That was the logical conclusion of an effort which started in 1935.

Important meetings

An international (essentially European and North American) macromolecular crystallography community had begun to take shape in the 1960s. The community then consisted of only a few dozens of persons. Therefore, it was possible to collect most of them in one place. During mid 1960s till mid 1970s. such meetings took place every two years at a skii resort called Hirschegg in the Austrian Alps. Although in Austria, Hirschegg was very close to Munich in Germany. The place was well known for its scenic beauty. The meetings used to take place in March/April. I attended the 1968 meeting alone and the 1970 meeting along with Kalyani. In 1968, I visited the then capital of West Germany, Bonn, Aachen at the border between Germany and Belgium, Amsterdam and Brussels on the way back from the meeting. I visited the laboratory of the famous scientist Zhan, on the advice of Dorothy. Insulin was first synthesized in three laboratories, one in America, and the other in China and the third in Germany. Zhan was the leader of the German group. In 1970, Kalyani and I visited Paris. I recall visiting the laboratory of a friend of mine, Jean Berthou who arranged our programme in Paris and giving a lecture at College de France.

The Hirschegg meetings used to be organized by Perutz and Hoppe who was a much respected professor at Munich. Macromolecular crystallographers made special efforts to attend these meetings. The participants included those who had already received Nobel Prizes and future Nobel Prize winners. Most of them went for skiing in the forenoons. We could not muster courage to skii. Instead, we went on long walks. Scientific discussions started after lunch and went on well into the night. The atmosphere used to be very informal. I presented the insulin results in the 1970 meeting. The meetings were scientifically extraordinarily useful. They also helped to cement many close personal relationships.

During my stay in Oxford, I had occasion to attend many conferences and went with Dorothy for many lectures at the Royal Society, London. The lectures and the discussion meetings at the Royal Society were extremely useful. Royal Society is the nerve centre of scientific activities in England. After leaving England, several decades passed before I visited the Royal Society again as the head of a sister Academy, when I was the President of the Indian National Science Academy.

A meeting which made a deep impression on me was the Bragg symposium held in April 1970, at the Royal Institution, London. The symposium was organized to mark the 80th birthday of Lawrence Bragg. Lawrence Bragg, who established the area of X-ray crystallography along with his father William Bragg, when he was in his early 20s lived to see the full glory of the subject. He has made notable contributions to macromolecular crystallography as well. It was when he was the head of the Cavendish laboratory, that the foundations of macromolecular crystallography in Cambridge were laid. In the 60s, he established a powerful protein crystallography group at the Royal Institution, when he was its Director. That is where the structure of lysozyme was determined by David Philips and his colleagues. Lysozyme was, after myoglobin and haemoglobin, the third protein and the first enzyme to be structure analysed.

The lecture hall of the Royal Institution, traditionally called 'the well' had been sanctified by lectures of great scientists like Davy and Faraday. Almost all the veteran crystallographers of that time were present at the Bragg symposium. Naturally, Dorothy was scheduled to give the talk on insulin. A couple of days before the symposium, she realized that no one from India was participating in it. Therefore, she decided that I should present the structure of insulin. I was then only a 28 year old post-doctoral fellow and was nervous about taking up this responsibility. At the same time, I was also excited about giving a talk along with so many well-known and distinguished scientists. Among the speakers, there were two more comparatively young scientists. One was Robert Huber who became famous later and received the Nobel Prize. The other was Louise Johnson who also attained great heights. She was a close friend of ours until her untimely death.

An amusing incident that I remember in connection with the Bragg symposium is the conference dinner hosted by the Royal Society. The tradition is that the 'usherer', attired colorfully, announces loudly the name of each guest when he or she arrives. It was difficult for him to handle some of the Indian names and used to get confused. When Gopinath Kartha who worked at Buffalo in the U.S. arrived, in confusion the usherer announced the arrival of 'Buffalo from Kartha'!

Continued association with Dorothy, other Oxford colleagues and Max Perutz

Mention has already been made about my colleagues in Dorothy's lab. Many more have worked with her, earlier as well as later. The one with whom I had many interactions in the future was Liang Dong Cai. He is a few years older than me. He took his doctorate from Soviet Union during the days of Soviet-Chinese bohemy. As indicated earlier, he worked briefly with Dorothy in the mid 1960's. He continued to work on insulin at Beijing. I had heard a great deal about him from Guy and others. It was apparent from his subsequent behavior that he had heard about me as well.

The relationship between Dong Cai and myself started when unexpectedly I received a New Year card from him in the early 1980s. Information on his life and work between 1966 and 1980 began to trickle in after that. As indicated earlier, his work on insulin continued without serious disruption even in the middle of the Cultural Revolution and the subsequent unsettling events. The close relationship that Dorothy had with Chinese authorities and leading scientists also helped Dong Cai. Her encouragement was also important.

I met Dong Cai for the first time in Beijing in 1986. It was at a conference organized by a Commission of the International Union of Crystallography, of which I was a member. China was then opening up and many famous scientists including Dorothy attended the meeting. By then, he had become Director of the Institute of Biophysics in Beijing. Since then, I have met him on several occasions in Beijing and elsewhere. Both of us were members of the Council of the International Union of Pure and Applied Biophysics for a period of time. As in my case in India, he was largely responsible for building up macromolecular crystallography in China. Like me, he was also encumbered with dreams of Afro-Asian solidarity. We became close friends. The last time I, along with Kalyani, met him was at the Biophysics Congress in Beijing in 2011.

I have had close interaction with many other former colleagues of Dorothy like Ted Maslen, Mike James, Jenny Glusker etc. Among the seniors at Oxford, David Philips was a great influence on me. I have already briefly referred to him. I had heard much about him, even before I came to Oxford. He has made many contributions pertaining to different aspects of crystallography. He was also involved with policy issues. He rose to become the main scientific advisor of the British government and also received a peerage. Many colleagues used to be slightly afraid of David. However, I had an easy and close relationship with him. He helped and encouraged me in abundant measure. Kalyani and I were hoping to meet him again when we visited the UK in 1999. However, he did not wait for us and died of cancer.

One who could be described as the godfather of macromolecular crystallography was Max Perutz. He was gentle and affectionate. He came to England as a refugee from Austria in the 1930s and started work on haemoglobin under the supervision of J.D. Bernal. Incidentally, he was once arrested during the second world war, on account of his German origin. In course of time, he rose to become a symbol of the positive aspects of English culture and humanity. Although he started work on haemoglobin in the mid-1930s, the crystal structure was solved only around 1960, for which, as mentioned earlier, he received the Nobel Prize. He continuously and thoroughly worked on different forms of haemoglobin from a variety of organisms. Through these studies, he made immense contributions to macromolecular crystallography and to the understanding of the structure and function of proteins. The path he followed was a model for others. In addition to carrying out his own research, he advised, helped and guided macromolecular crystallographers and structural scientists around the world. He was a prolific writer and has produced many articles and books.

Dorothy and Max were close friends. Both were honoured with the Nobel Prize nearly at the same time. Both were conferred the Order of Merit. Both of them were living symbols of simplicity and human goodness. I became reasonably close to Max. Until he died in 2002, I used to visit him at Cambridge, whenever I went to England. In addition to his affection and hospitality, he always provided new insights to me. My students and colleagues organized an international symposium in Bangalore in 2001, to mark my 60th birthday.

By the time, Max had cut down his travels on account of ill health. In any case, the organizers would not have mustered courage to invite him to the symposium. However, Max came to know about the event. He then sent an autographed book of his as a birthday gift, through my friend Guy Dodson who naturally attended the symposium. I was deeply touched when a famous scientist occupying the dizzy heights of achievements showed his affection and generosity to me.

Dorothy was the lodestar in our lives. We have been in constant touch with her till her death in 1994. She has visited India several times. Thomas also accompanied her once. She always brought an appropriate gift to our daughter (her God-daughter) whenever she visited us in India. The last time I saw her was at the Crystallography Congress in Beijing in 1993. By then she had become very frail. She came to Beijing against the advice of her doctors. It appears that she told the doctors that she would not mind even if she died in China. Though silent, she was an all pervading, vibrant presence in the Beijing Congress.

We continued to be in touch with our other Oxford colleagues. We also got together once in a while, in one meeting or another. Each one of us has made an impact in one's own field of activity. All of my Oxford colleagues have visited India several times. The relationship with us served to some of them, as a window to India. I recall Ted Baker mentioning that "India came alive to me through Vijayan" in the symposium associated with my 60th birthday. The last time we all assembled together was at Auckland in 2012 at a symposium to celebrate Ted's 70th birthday. Soon afterwards, Guy, dear to all of us, passed away. The symposium at York associated with his formal retirement at the age of 67 in 2004, was an occasion in which Kalyani, myself and all our Oxford colleagues got together. Eleanor continues to be active. She has subsequently visited us a few times. She is much admired and loved in the community.

My stay at Oxford during 1976-77 was interesting and personally very rewarding. However, it is the 1968-71 stint that turned out to be a turning point in my life. My transition from Physics to Biology took place primarily during that period. Modern biology encompasses Physics, Chemistry and much else. It was the experiences of that period and the lessons I learnt then that served as a foundation stone for my future career. When I left Oxford and returned to India in early 1971, I was the first trained macromolecular crystallographer to return to the country. My home coming then turned out to be the beginning of a long, and still continuing, chapter in my life.

4

A DIGRESSION. BONDING IN BENGALURU, MARRIAGE AND CHILDBIRTH IN OXFORD, FAMILY

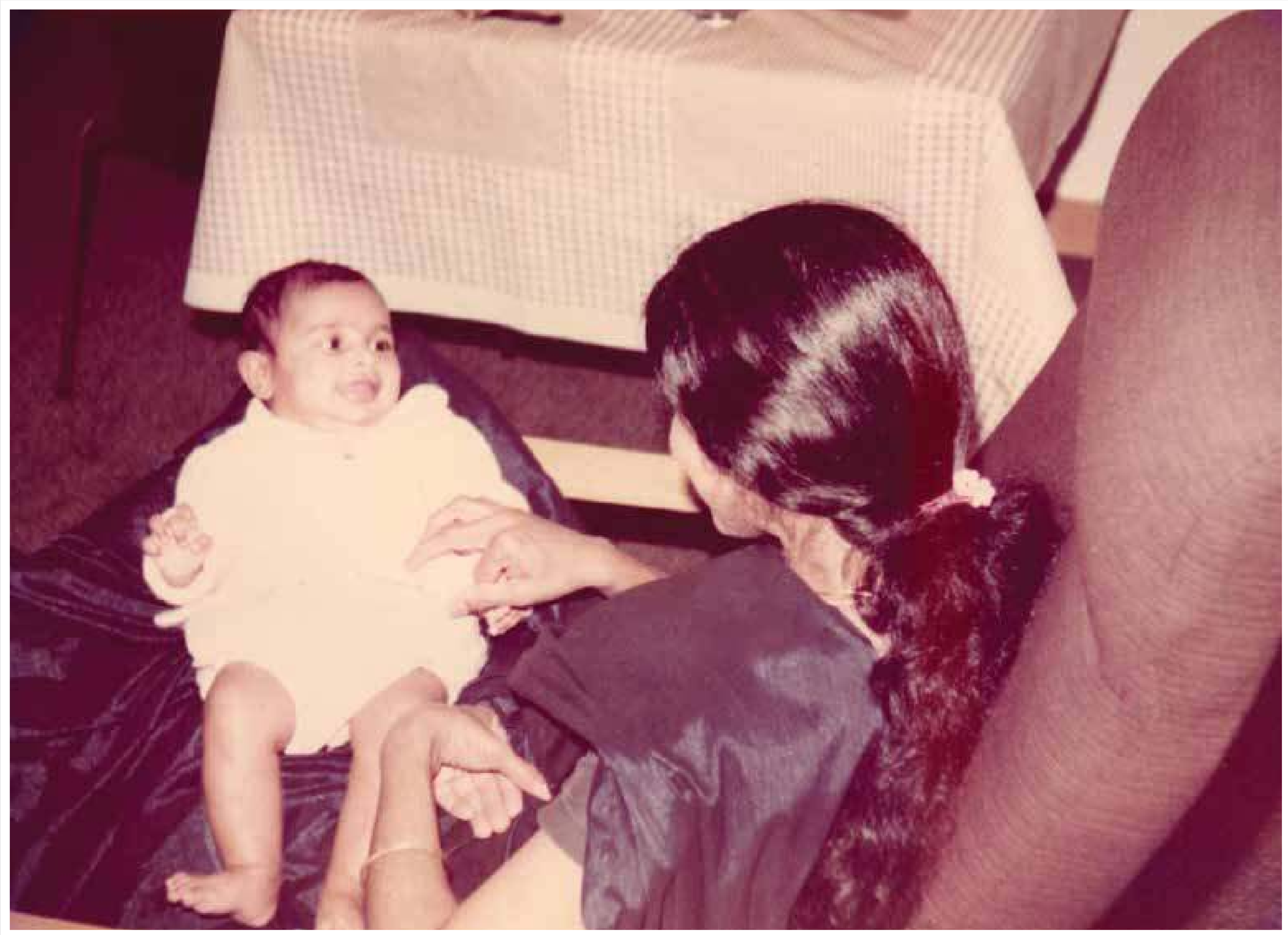
Kalyani joined the X-ray group in the Department of Physics of the Indian Institute of Science in 1964. As I learnt later, her ancestors belonged to Mannargudi in Thanjavur district. She spent her childhood at Madurai and moved to Chennai when she was about 10. She completed her schooling in St. Raphael's and obtained her B.Sc. degree in Physics, studying in Queen Mary's college. She studied in Presidency College for her M.Sc. degree, again in Physics. She obtained first class in SSLC, Pre-university, B.Sc. as well as M.Sc. examinations. It was with this impressive record that she joined the Institute for research. She started her doctoral research under the supervision of H. Manohar who had by then obtained Ph.D. degree and was on the look-out for an independent position elsewhere.

Being students in a small group, Kalyani and I got to know each other well. By the end of 1965, I was mentally committed to her. She was in ostensible denial, but I was not entirely sure that she was impervious to my entreaties. In the middle of 1966, I went to Mumbai to use the computer at TIFR in connection with the final stages of my doctoral work. That was also a vacation from a two year long togetherness and afforded an opportunity to assess one's feelings. The sojourn turned out to be longer than anticipated, as I spent three weeks in a contagious diseases hospital in Mumbai, as I contracted chicken pox. However, I returned only after completing the work. By then Kalyani was also committed to me and thus ended the period of uncertainty.

A family photograph just before departure for Oxford.
Front row (L to R) : Father, grandmother, mother.
Back row (L to R) : Indira, Vijayan, Ravindran and Surendran. Vijayan is carrying Mini.

Kalyani and Vijayan in Summertown House, after their marriage in 1969.

Dorothy and Kalyani in Ilmington



Kalyani with baby Devi

In the meantime, Manohar left the department to take-up a permanent position in the Department of Inorganic and Physical chemistry. Viswamitra had already left for Oxford. Therefore, I was primarily responsible for supervising the final stages of Kalyani's Ph.D. programme. An interesting interlude during this period was a trip to Mumbai by both of us to carry out computations at TIFR. She stayed with her friends and I with mine and we spent time together primarily at the computer centre of TIFR. However, it was a wonderful experience. We worked together and most often ate together in the TIFR canteen. Occasionally, we went out to eat. I particularly remember the Gujarathi restaurant called Purohit on the way from Churchgate to Victoria Terminus.

By the time we returned from Mumbai, preparations were on for my departure to Oxford. Kalyani's doctoral work was completed before I left. Her thesis was also almost ready. It was anticipated that the submission of the thesis and the formalities associated with examination would take some more time. We then decided that Kalyani would stay back and I would come back after two years to get married.

As indicated earlier, the insulin work in Oxford was showing great promise by the end of 1968. It was clear that we were proceeding in the right direction and the structure determination of the protein was not far away. Dorothy felt that it was desirable and good for everyone concerned, to keep the insulin team intact for some more time. One day she told me that it was desirable for me to stay at Oxford beyond the two years envisaged originally. I was in a dilemma as my agreement with Kalyani was to return after two years. I presented the problem before Guy and Eleanor, my elders in the laboratory. They unambiguously advised me to talk about it to Dorothy, which was what I did. She was very pleased to hear about the relationship. According to her, what was required was not for Vijayan to go back to Bengaluru but for Kalyani to come to Oxford. She offered all help to make it possible. By then, Kalyani had obtained her Ph.D. degree.

There was some concern as how to realize this inter-community marriage (Iyer-Nambudiri, Tamil-Malayalam) with the two of us sitting thousands of kilometers apart. The primitive nature of communication systems that existed at that time added to the worry. Fortunately, there was no objection from the two families. I had earlier visited Kalyani's parents during the National Seminars on Crystallography at Chennai. My parents had met Kalyani when they visited me at Bengaluru. Although we felt that it was not necessary, Kalyani's parents made it a point to go to Cherpu to meet my parents. Subsequently, the pleasant relationship between the two families became stronger in course of time. Even though it took some effort, we could persuade them to allow us to marry in Oxford. It took a few months for Kalyani to wind up her efforts in India.

In the meantime, Dorothy supported Kalyani's application for the 1851 Exhibition Fellowship. She was selected from India after an interview in Delhi. Apparently, the list was not forwarded to England in time by the concerned authorities. We were told that the authorities in London did not condone the delay in the submission of the list from India, as they were going through a financial crisis. Once she came to know of this development, Dorothy offered support from her own grants.

Kalyani arrived in England on July 10, 1969 at a time when the insulin work was at its peak. By then, I had arranged a centrally heated flat in Summertown House associated with the University. All the colleagues welcomed Kalyani warmly. I recall Thomas Hodgkin telling 'Dorothy thought that she was losing a son, but instead she gained a daughter'. Our marriage was registered on 14, July, 1969 in the presence of Dorothy, Thomas, Guy, Eleanor and other colleagues and friends. Subsequently, the wedding party was held at the home of Guy and Eleanor. As the insulin work was at a critical stage, I returned to the lab on the 15th itself. Kalyani also joined the efforts.

After the completion of that stage of the insulin work, Dorothy left on August 6 for the Crystallography Congress at Stonybrook with slides for her presentation. The very busy period thus came to an end. Kalyani and I then spent a couple of days roaming around in London. Subsequently, we, along with our old friend T.R.S. Reddy and his wife Sreelekha, went to Edinburgh. Another old friend of ours, R.S. Katiyar, was then at Edinburgh. All of us together spent a few happy days in the city. Towards the end of the Edinburgh holiday, we got a telegram from Dorothy asking us to attend the Biophysics Congress scheduled to be held in Boston during the end of August and beginning of September.

We spent two weeks from August 28, in USA. Dorothy provided the airfare for both of us. We were expected to meet the living expenses in America ourselves. In Boston, we stayed with Sani, my old friend and former student of the Institute. His wife Celine was also a former student of the Institute and a friend of Kalyani. All our travels in the USA were by Greyhound bus, as we could not then afford airfare. After the Boston Congress, we went straight to Washington D.C. to be with Kalyani's elder brother Balasubramanian (Balu). We then went to New York and stayed with V.G. Malathi, a student of my father at Cherpu and a student of the Institute, senior to us. We also visited Stonybrook where our hosts were C.V. Krishnan and his wife, Nalini.

In addition to personal visits, we had discussions with Barbara Low, an old associate of Dorothy at Columbia University and with structural biologists at the National Institutes of Health, near Washington. I also vividly recall the discussions we had with Har Gobind Khorana, who had just then got the Nobel Prize, at a dinner in Boston.

After returning from US, Kalyani started her own work with Dorothy on a cephalosporin analogue. She was ensconced in the Chemical Crystallography Laboratory where Dorothy's small molecule group was located. Every day, Kalyani used to walk through the University museum to

LMB with packed lunch. The huge skeleton of a dinosaur in the quadrangle of the museum was a mute spectator to her passages through the museum. We did not properly see the museum. We thought we could see the museum any day as it was located so near to our laboratory. But that day never came!

We had a very busy social life in Oxford, primarily involving our colleagues. Among Indians, those closest to us in Oxford were Reddy and Sreelekha, also staying in Summertown House. Reddy was then working in the Clarendon Laboratory. The Indian family closest to us in England was that of Ramakrishna Menon, which then consisted of, apart from himself, his wife Sarada, children Latha and Lekha, and Sarada's mother Kalyaniamma. Kalyaniamma was earlier a teacher in the Cherpu school. Our social ambience was very cosmopolitan and involved friends from all continents.

After completing our work at Oxford, we started for India on January 8, 1971. On the way, we spent a few days in Rome. Our Oxford colleague, Sophia Candellora helped us organize our arrangements. We began to feel at home when we reached Rome. Things, especially traffic, are more disorganized in Rome than in England, but not as disorganized as they are in India. Also, people are voluble and spoke loudly in the streets, unlike in England. People were very warm and human. We visited Sophia's home more than once. When we left, her mother wished us many children, again an Indian touch!

The trip from England to India was eventful, as we were travelling using cut-price tickets by United Arab Republic (a short lived union of Egypt and Syria) airlines. They kept losing landing rights at airports. In that confusion, we travelled from Rome to Cairo by the Ethiopian airlines. The next stop was Doha. The Doha airport was then very small. The plane developed a snag after it took off from Doha. We had a tense time while the plane returned to the airport after shedding the fuel it was carrying. With a cut-price ticket, we had no option but to travel by the same aircraft when it took off. By the time we reached Bombay, we were several hours late. Kalyani's sister Karpagam and her husband Sundaresan were patiently waiting at the airport to receive us.

After a brief stay in Bombay with Karpagam and Sundaresan, we proceeded to Kerala by train. At Arakkonam junction, Kalyani's parents came with a bunch of traditional gifts appropriate for a newly married daughter and son-in-law. We stayed in Kerala for a couple of weeks. That was the first introduction of Kalyani to my extended family and relations. She gained instant acceptability among all of them. Some expected to see a highly westernized lady. Her traditional ways impressed them. Subsequently we stayed for a few days with Kalyani's parents in Chennai. That again was my first introduction to her close relatives and friends. From Chennai, we came to Bengaluru in early February, 1971. I joined the Physics Department of the Indian Institute of Science in an *ad hoc* position and Kalyani joined the National Aeronautical Laboratory a couple of months later as a CSIR Pool Officer.

Unexpectedly, the next few years turned out to be difficult, professionally (see later) and personally. Kalyani conceived in late 1971 and the baby was expected in 1972. A breech presentation was detected and a caesarian section was performed. The baby girl turned out to have a developmental disorder called spina bifida and survived for less than a month. The next delivery was in 1974. Close to due date, some weakness in the heart beat of the baby was detected. A caesarian section was immediately performed but it turned out to be a still birth. We were devastated, but continued with our work in the respective laboratories. We were of course in constant touch with Dorothy. After the first delivery, she wrote that, according to her doctor friends, there was no clear idea about the causes, early diagnosis and cure of spina bifida. A couple of years later, she informed us that a test was now available for early detection of disorders such as spina bifida. It turns out that the test would, *inter alia*, provide information about the gender of the foetus also. It is this information which came to be widely misused in India later.

In the meantime, Kalyani secured a permanent scientist position at NAL and I was appointed as an Assistant Professor in the Molecular Biophysics Unit (MBU) at the Institute. In 1975, I received an invitation from Dorothy to work in her laboratory during 1976-77. She was scheduled to retire in September 1977, at the age of 67. She wanted one of her old colleagues to help her to wind up the work. Knowing Dorothy as we did, we were certain that our health issue was also on her mind.

In normal circumstances, it was inappropriate to take leave from our jobs so early after our appointments to permanent positions. However, Dorothy's invitation was irresistible. As we were despondent in relation to child birth, it was sensible to take a last chance in England. Seniors in both the organizations were enthusiastic in supporting us. There was an additional complication in that any foreign trip was looked upon with suspicion as the national emergency had already been declared. I recall G.N. Ramachandran personally taking me to the Director, Satish Dhawan, to convince him of the need for me to go to Oxford for one year. Similarly. S.R. Valluri, the then Director of NAL, personally took the papers to CSIR headquarters in New Delhi to obtain leave for Kalyani.

In addition to offering positions for Kalyani and myself in the laboratory, Dorothy also arranged a Senior Visiting Fellowship for me at the Wolfson College in Oxford. In Oxford University, colleges are places where scholars lived, in addition to carrying out other academic activities. We were allotted a very convenient two room apartment at Wolfson. Wolfson College is close to the university and is separated from the University Park by the Cherwell river. An extension of the Cherwell river into the college formed a pond where swans frequented. From Wolfson college, we could walk to the university either through the park on the left or by road on the right.

Only Dan Mercola was still in Oxford in 1976-77 from the 1968-71 team. He had by then moved on to another project. A new colleague we acquired was Barbara Brodsky who is well known for her work on collagen. She had joined the lab to acquire familiarity with single crystal work. During the short time we were together, we became very attached to Barbara. After we left Oxford, we met Barbara again decades later, when she visited India. Ramakrishna Menon's daughter, Latha, was doing her degree in Physics during that period. We used to meet her and the Menon family frequently. The social life during 1976-77 was also vibrant. Towards the end of our stay, most of the old colleagues came to Oxford to participate in the European Crystallography meeting in September 1977 in honour of Dorothy.

By the time we reached Oxford in late 1976, Kalyani was pregnant. During 1968-71, we had hardly any contact with the famed National Health Service (NHS) of the UK. This time, it was different. In view of the past history, our G.P. referred Kalyani to the John Radcliffe Hospital in the suburbs of Oxford. The doctors at the hospital periodically monitored the progress of pregnancy. They also carried out appropriate tests and verified that the foetus had no genetic or developmental problem. They offered to tell us the gender, but we did not want to know it in advance.

That was the time when Thomas Hodgkin was unwell. Almost everyday in the morning, Dorothy and I exchanged notes on the conditions of Thomas and Kalyani, before starting work. On account of the previous history, the doctors had decided on a caesarian section for Kalyani. By May 9, 1977, the operation was fixed for May 12. When I informed Dorothy about it, she exclaimed "May 12 happens to be my birthday!". That was very auspicious. Dorothy was such an optimist that she invited Guy Dodson from York for dinner on May 12 to celebrate the new arrival! We, of course, got into a celebratory mood only after the baby girl was born through caesarian section at 1217 hours on May 12, 1977. As arranged, I joined Dorothy, Thomas, Guy and Guy's house guest Bill Duax for dinner in an Italian restaurant in Oxford. Kalyani was of course still in the hospital.

By the time Kalyani and the baby were brought home to Wolfson college, Dorothy had provided us with a baby cot, a baby bath tub and other accessories. She never let us feel that our parents were not with us. After much thought, we named the baby Devayani Dorothy. Most people call her Devi for short. We rejoiced in adding 'Dorothy' to her name as she was born on Dorothy's birthday. By a happy coincidence, Florence Nightingale who was the first woman to be honoured with the Order of Merit (the second was Dorothy), was also born on May 12!

After the arrival of the baby, one tension from our lives gave way to happiness. The five months of our subsequent stay in Oxford was very pleasant. Kalyani was naturally at home during this period. I was busy in the lab winding up the work and occasionally I used to resent having to be in the lab away from the baby. In early October, 1977, we left Oxford for Ilmington. After staying with Dorothy and Thomas for a couple of days, we left for London to be with the Menon family, again for a couple of days. While at Ilmington, there were three Dorothys in the house, Thomas' mother Dorothy, Dorothy the scientist and baby Dorothy! From London, we flew to Mumbai and then to Bengaluru.

While Kalyani and I, now with Devi, were settling down, my siblings also were going through the same process. My sister Indira got married in the early 1960's to Vasudevan, whom we call Vasudevettan. Their first son, my first nephew, Vinod was born in early 1966. Their daughter, my first niece, Mini, was born in the second half of 1967. The third child, a boy, Happy was born in 1970. Thus, when we returned home after our first stay in Oxford, we had two nephews and a niece in Kerala. During our difficult days in the 1970s, they were our main objects of affection. Indeed, they gave us great deal of pleasure. They still continue to do so.

My brother Ravindran did his M.Sc. in Physics and joined Farook College near Kozhikode as a lecturer in the early 1970s. Around that time, my father retired as the Headmaster of the CNN Boys High School. Ravindran married Nalini in 1975. She came from a family very well known to us and her father was an activist of the undivided Communist Party. The wedding was attended by many well-known communists including EMS. Subsequently, Nalini taught in a school at Farook. My youngest brother Surendran, the brightest among us, took his MBBS from JIPMER, Pondicherry in the 1970s. He married Savithri, also a doctor, in 1977. Savithri also hailed from a family very well known to us. Surendran went on to do his M.S. from Maulana Azad Medical College, New Delhi and FRCS from London as well as Edinburgh. Savithri also practiced while they were in the UK. Two girls, Swapna and Sandhya, were born to them in the early 1980s. The family returned to India in 1986.

Kalyani's elder brother Balu has been settled in USA for decades. He has three daughters, Sujatha, Sarita and Sandhya. His wife Kamala hailed from Erode in Tamil Nadu. Kalyani's parents and younger brother also migrated to USA around 1980. Her sister Karpagam and brother-in-law Sundaresan spent most of their lives in Delhi. Sundaresan was associated with DCM as a computer expert until he resigned the job and became a freelancer. They have three boys, Subash, Prakash and Vijay. Like most Indians, the extended family was very important for us. Devi grew up with close relationship with all her uncles, aunts and cousins. The relatives beyond the immediate extended family also touched our lives in different ways.

5

IN A NEW PATH WITH OLD ENTHUSIASM

As indicated earlier, I completely stopped all political activities when the Communist Party of India split in 1964. They had in any case progressively dwindled since I left Kerala in 1961. To a substantial extent, I lost direction in life after the split. Although I was deeply immersed in scientific research, I was despondent. I felt that life was useless unless it was oriented towards serving the downtrodden. It was during that period that I became close to Kalyani, which provided solace. It was also then possible for me to help the family in a small measure using savings from my scholarship. That also provided a direction to my life. Still I was restless.

It was when I was working on the three dimensional structure of insulin as a post-doctoral fellow in Dorothy's laboratory during 1968-71 that I regained my equanimity. Looking back, the determination of the three-dimensional structure of insulin was a historic event in science. It was my great good fortune that I could take part in that effort. The expertise and perspective that I gained and the relationships that I established during that period stood me in good stead during the rest of my career. Our life in Oxford had a social, cultural and political aspect also. As indicated earlier, Dorothy and her husband Thomas were strong leftists and humanists. They engaged with the famous, revolutionaries and refugees with equal ease. I have had opportunities to participate in these engagements. Although not communists, most of my colleagues in Oxford were also strong leftists. The stay in Oxford also provided an opportunity to read many books, particularly on contemporary history, making use of the main Oxford library.

That was the time when the Vietnam War was approaching a decisive end. The rivalry between the Soviet Union and China was acute. The terminal decline of the communist movement in Western Europe had begun. The process described by MacMillan as "winds of change" was in full swing in Africa. Latin America was turbulent. That was also the time when the new Left involving Tariq Ali and others was much in evidence. The occupation of Czechoslovakia by the Soviet Union in 1968 was reminiscent of the events in Hungary in 1956. Needless to add that it did not enhance the reputation of the Soviet Union. I recall myself participating in a protest march in Oxford against the occupation of Czechoslovakia. I had occasion to mix with many refugees from that country. Many of our colleagues were from Eastern Europe. We also had an outspoken colleague from Moscow. All these interactions persuaded me to revise my approach to the Soviet Union and East European countries as paradigms worth emulating.

The experiences outlined above helped me develop a more inclusive and comprehensive world view. Like Darwinism in biology, Marxism brought revolutionary changes in social sciences and economics. Incidentally, Darwin and Marx knew and respected each other. Over decades, Darwinism was creatively enriched and elaborated, and remains the centre piece of biology. Marxism to an extent became the ideology of the establishment with the advent of the Soviet Union and other socialist states. That substantially stunted the development of Marxist theory and its capacity to absorb new experiences. One casualty in the process was the near disappearance of Marxian humanism from the discourse. Even in the Oxford days, I used to feel the need for deliberate steps to free Marxism from the authoritarian framework and enrich it through creative intervention. This is particularly important in the present age of globalised, aggressive, predatory capitalism.

Recognizing contradictions and handling them properly are at the core of Marxist practice. The argument that the most important contradiction in the present times is between the comity of advanced countries comprising North America, Western Europe, Japan etc. on the one hand and the developing and under developed countries of the world on the other, appeared acceptable to me. In my youth, India was certainly in the second group. In my view, the situation still remains substantially the same, although the ruling circles sometimes exhibit a tendency to align with the affluent countries. Therefore, there is an ideological basis for determined effort for strengthening India. Such efforts are also in consonance with the secular nationalism advocated by Nehru and like-minded people. Nationalism of the strong can become dangerous. On the other hand, nationalism of the weak can be turned into a creative, progressive force. It is this approach, with substantial emotional content, that guided me for the rest of my life after my return from Oxford in 1971. My commitment was not only to science, but also to India. To an extent, this was a continuation of my earlier political commitment. Over the years, my original ideological moorings got relegated into the background and involvement with Indian science and mentoring of young scientists, in their own right, became my main pre-occupation.

6

INDIAN INSTITUTE OF SCIENCE. OUTLINE OF A LIFELONG ASSOCIATION

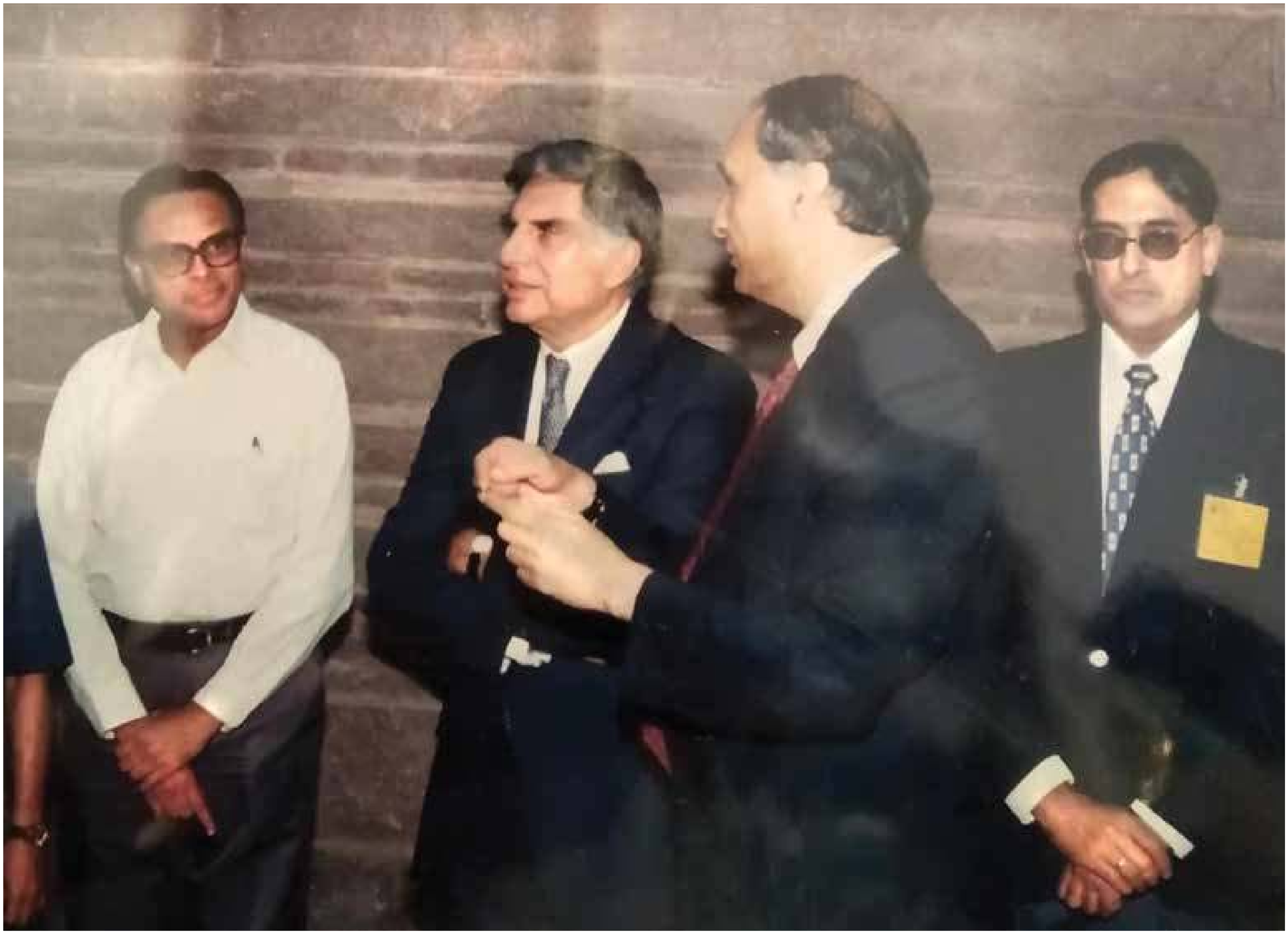
Even when I left the Institute in December 1967, after obtaining my Ph.D. degree, R.S. Krishnan had indicated that I would be welcome back in the department as a faculty member, after I completed my post-doctoral stint. In spite of some confusion in between, the idea was revived in the second half of 1970 and took a concrete form when Satish Dhawan, the Director, visited Oxford in September, 1970. I met him by appointment and his response to my request was unambiguous and positive. He said "We know you and your work. I can straight away offer you an *ad hoc* position equivalent in status to that of an Assistant Professor. Come back to Bangalore and by the time you find a house to live in, I shall get you an Assistant Professorship". It is to that *ad hoc* position in the Physics Department that I returned in February, 1971. Subsequently, Kalyani joined NAL as a CSIR Pool Officer and she was absorbed into the permanent scientific cadre in 1973.

Second Innings in Physics. Uncertainty and hope

The situation in India had changed dramatically by the time we settled in Bengaluru in 1971. The crackdown in erstwhile East Pakistan started and resulted in the exodus of millions of refugees to India, causing severe financial crisis in the country. I understand that a decision was taken to defer fresh appointments to all old departments. Furthermore, Dhawan was on sabbatical for a year during 1971-72 and got busy with the Chairmanship of the Space Commission, on his return. My agreement regarding appointment was exclusively with Dhawan and I was therefore left high and dry

A. Sridharan and Vijayan talking to a visitor in the1990s.

Vijayan, C.N.R. Rao and G. Padmanaban at a function in the mid 1990s.



(L to R) : Vijayan, Ratan Tata (President, IISc Court), Goverdhan Mehta and Uday Balakrishnan.

Kalyani and Vijayan with President A.P.J. Abdul Kalam.

Receiving on behalf of IISc, the G.N. Ramachandran Endowment from Murli Manohar Joshi at a function in NII in 1999.

Felicitating Venki Ramakrishnan at IISc in 2002.

in the *ad hoc* position. Another colleague of mine, S.K. Podder, was also in a similar situation in the Biochemistry Department. He had come back to India with a reputation of having done excellent work with Manfred Eigen, a Nobel laureate. Both of us spent long periods in *ad hoc* positions before obtaining regular faculty positions.

By that time, R.S. Krishnan, who originally mooted the idea of my returning to the department, had given up the headship of the Physics Department, but was continuing in the department prior to his departure as the Vice-Chancellor of Kerala University. No one else in the department had any commitment in relation to my job. However, I was treated very well and accorded all the privileges of an Assistant Professor. I shared the lab with Viswamitra, my former guide. Two students were allotted to me for guidance. The first was Tej Pal (T.P.) Singh in 1971 and the second T.N. Bhat in 1972. They laid the foundations of my early efforts as an independent researcher. I also participated in the teaching programme of the M.Tech. Course in Physical Engineering that the department was conducting during that period. I also taught crystallography courses for research students.

Around the time I returned, an interdisciplinary Molecular Biology Group, drawing faculty members from different departments, was formed with T.M. Jacob as the Convener. That was a period when there was some controversy about molecular biology. Some alleged that molecular biology is the illegitimate practice of biochemistry. Some considered the subject as exclusively concerned with nucleic acids while some others averred that biology at the molecular level is molecular biology. The Journal of Molecular Biology subscribed to the latter position. The fact that I was admitted to the group meant that this position was accepted by the Institute as well. I offered courses on the three dimensional structure of proteins under the aegis of the Molecular Biology Group. In addition to my research students, those who attended these courses included S. Ramakumar, T.N. Guru Row and M.R.N. Murthy, all of whom later became my valued colleagues. The others whom I taught during that period included M.V. Hosur and A.M. Shaik.

In a sense, I brought three dimensionality in biology to the Institute. I recall building the model of the three dimensional structure of insulin with the help of a summer student, using Dynam model bits. No one in Bengaluru had till then seen such a model. An important commemorative conference took place in the Biochemistry Department during that period. At the instance of T.M. Jacob, I constructed the model of DNA for an exhibition connected with that conference. One of Jacob's students who helped me in this effort was Sulbha Gupta (then Karandikar) who was of great help to me later when she was an officer in the Department of Science and Technology. Apparently, that model was even airlifted to Delhi for an exhibition there! I also recall making the plastic model of a bacteriophage for Joseph Padayatti. I continued the habit of constructing three dimensional models of different proteins, until computer graphics became common place. I recall my collaborative interactions with T. Ramasarma of Biochemistry as well. They led to lifelong friendship with Ramasarma.

In addition to the faculty members from student days, the new person whom I came to know well during my second stint in the Physics Department was N. Kumar. We were nearly of the same age. He was a theoretical physicist, but his interests went well beyond it. He had a bubbly personality. I very vividly recall many animated conversations with him on different topics in science. Our close relationship continued even after I left the department. In essence, our careers progressed in parallel. We received the Bhatnagar Prize in the same year (1985). Both of us were elected to the Indian Academy of Science, Bangalore in 1983 and the Indian National Science Academy, New Delhi in 1987. There was a time when Kumar was the Chairman of the Physics Department and I, of the Molecular Biophysics Unit. For a short period, we worked together as Divisional Chairmen, he of the Physics and Mathematics Division and I of the Biological Sciences Division. Kumar was the Director of the Raman Research Institute while I was the Associate Director of the Indian Institute of Science. He went on to become the President of the Indian Academy of Sciences, while I became the President of the Indian National Science Academy at a different period. There were other similarities in the positions we held and the recognitions we received as well. During all these decades, we remained friends and kept in touch with each other till his death in 2017.

Although I was happy academically, I was naturally very worried about the uncertainty about my formal position. So was R.S. Krishnan. However, by that time, he had formally retired and was in no position to help me. He advised me that regardless of all other difficulties, I should concentrate on my research work. Ultimately, that is what matters in the long run. I took this advice seriously. By the early 1973, I came to know that there was a move to create two positions of Assistant Professor, one in Biochemistry and the other in Physics for Podder and myself, respectively. During the same period, one day I had an unexpected call from GNR asking me to meet him. He told me that he wanted to start X-ray crystallography studies also in the newly founded Molecular Biophysics Unit (MBU) and he thought that I was the best person to initiate such studies in MBU. I was of course flattered. The choice was to wait for the incipient position in Physics or accept GNR's offer and wait for a position there. I opted for the second alternative and I was for all intents and purposes part of MBU from the first half of 1973. Here again, there was frustrating delay in regularizing my position as Assistant Professor. That happened only in April 1974.

From 1973, MBU has been the platform for my scientific activities. It is therefore appropriate that I set apart a separate chapter for my involvement with MBU.

Dhawanian evolution. The restructured Institute

The Institute in the early 1970s was substantially different from what it was when I was a student. The transformation was brought about primarily single-handedly by Dhawan. He became the Director of the Institute in 1962 at a comparatively young age. For all practical purposes, the institute was then divided into several silos. By and large, each department was a silo with a permanent head of the department. Towards the middle of Dhawan's tenure, the practice of appointing a new Head of the Department on the retirement of the incumbent, was discontinued. Instead, a Professor-in-Charge was made responsible for running the department. Very soon, the designation "Professor-in-Charge" was changed to "Chairman". By the early 1970s, this transformation was effected across the Institute. It was also stipulated that the major decision making powers would rest with the Committee of Professors and the departmental faculty. Thus, the head of the department ceased to be all-powerful. The Chairman held office at the pleasure of the Director. There was no fixed tenure. By and large, seniority was followed in choosing Chairmen but not always. This arrangement did not lead to serious difficulties as Chairmanship was not something which everybody aspired for. Most of the professors were distinguished in their own right and Chairmanship often did not add much to their stature.

In pursuance of the recommendation of a Visiting Committee, the departments were grouped into a few divisions, while retaining some centres under the direct control of the Director. The divisions then were those of Physics and Mathematics, Biology and Chemistry, Electrical Sciences, and Mechanical Sciences. Each division was headed by a Chairman, who, again, held office at the pleasure of the Director. There have been many discussions on the role of Divisions and I recall serving as a member of a Committee to formulate recommendations on this issue. We recommended that a Divisional Chairman should be a natural leader of the faculty members of the division, in addition to having the confidence of the Director. The roles of Divisional Chairmen acquired clarity in course of time.

With the restructuring outlined above, the organization of the Institute underwent a sea change. The boundaries of departments became diffuse. Inter-departmental and inter-disciplinary interactions became the norm. In effect, the only strong authority in the Institute became the Director. Fortunately, the Director during the period of transition was an enlightened leader like Dhawan. Institute bodies like the Senate and Faculties remained strong and influential, and no Director could easily bypass them.

Dhawan exerted great influence on the Institute and on many of us. He was a natural leader endowed with great charisma. He was a Nehru-like personality. When faculty members went to him, it was usually with some request. The request may or may not be acceded to, but one always came back with a sense of elation for having spent time with a great person. Only once I have seen him visibly disturbed. That was in

1975 when Dhawan was concurrently the Director of the Institute and the Chairman of the Space Commission. That was the only occasion when I have seen him smoking in public. As we began our conversation with him, he asked us whether we were bringing him good news or bad news. That again was so much unlike Dhawan, who apparently never worried about bad news. Soon after this particular encounter with him, we read the news that India's first satellite, Aryabhatta, has been successfully launched. On the occasion of our meeting with him, Dhawan must have been tense about the success of this first launch. Even a great person like Dhawan could occasionally become tense and nervous like us, ordinary mortals!

Dhawan engaged himself with faculty members of all ages. Occasionally, he organised unstructured discussion meetings in which senior and junior faculty were represented. One such meeting in the 1970s which I distinctly remember, but have no record on, involved scientists form ISRO as well as the Institute. The guest at the meeting was Nurul Hasan, the then Minister of Education at the Centre. His was a substantial presence, literally as well as figuratively! It was in that meeting that I saw Kasturirangan for the first time. I was then a young Turk at the Institute. He must have been one in ISRO.

Early forays into Institute affairs. Student unrest and Faculty Association

I began to be drawn into the affairs of the Institute after I became a regular faculty member. One of the early efforts I distinctly remember had to do with student unrest. Research admissions to the Institute used to be based on marks obtained in university examinations. With the proliferation of universities in India, it was perceived that uniformity in examinations was impaired. Therefore, the Institute introduced its own entrance examination. Conduct of entrance examination involved considerable expenditure and effort. After a few years, many faculty members felt that inter-university variability in marks was not large enough to warrant conduct of a separate entrance examination. After a great deal of discussion, it was decided to go back to the old system of admission based on performance in university examinations. A substantial section of students, particularly from the East, rose in revolt against this decision. Dipankar (D.D.) Sarma, who later became a close colleague of mine, was one of the leaders of the agitation. It was pointed out, for example, that the Calcutta University was very conservative in awarding marks, while some other newly started universities were very generous.

Student agitations were unusual in the Institute. Authorities, including Dhawan, were taken by surprise by the intensity of the stir. I was then a young faculty member and, as young faculty members usually are, was on easy terms with students. I was a faculty member to whom Dhawan turned for help. After protracted negotiations, we decided to revisit the issue. This process involved working in a high power committee chaired by Roddam Narasimha. Incidentally, it was then that I got to know him well. Eventually, entrance examinations were restored.

In spite of the great acceptability of Dhawan, considerable disquiet developed among sections of the faculty by the late 1970s. From the early 1970s, Dhawan headed ISRO as well as the Institute. Dhawan's success in the restructuring of the Institute substantially rested on his involvement with all aspects of Institute administration. That was now no longer possible. Many felt that under pressure he was acting abruptly and was not paying sufficient attention to representative bodies like the Senate and the Faculties. This led to the formation of the Faculty Association. I was involved with the Association from its inception. We were clear that it was not a trade union. The effort was to strengthen institute bodies with emphasis on participatory democracy. To start with, Dhawan was taken aback when the Association was formed. But, generous and sensitive that he was, Dhawan creatively engaged with the Association.

The Association took up many issues. One of them had to do with assessment and promotion of faculty members. In response to a request from the Association, a committee headed by A.R. Vasudeva Murthy was formed to examine the issue. I was the youngest member of this committee and was virtually its secretary. Much of the work of the committee was done when the Director was S. Ramaseshan who succeeded Dhawan in 1981. The recommendations of this committee formed the basis for the procedures of promotion and assessment of faculty members in the Institute.

Another important issue taken up by the Association was housing. In earlier days, housing was plentifully available for rent, close to the Institute, particularly in Malleswaram. Land prices were also reasonable for faculty members to build their own houses near the Institute. The situation changed dramatically in the 1970s, with the rapid expansion of Bengaluru. Unlike in earlier days, faculty members now wanted accommodation on campus. The few dwelling units, many of them British era bungalows, were grossly inadequate to meet the requirements. The Faculty Association therefore wanted to press for the construction of more quarters. In this context, the Association requested the Chairman of the Governing Council to meet faculty members, when he came for the March, 2001 meeting of the Council and the Court. The Court, largely ceremonial, is the highest body of the Institute and was then chaired by J.R.D. Tata. The response of the Chairman of the Council to the request of the Association was negative. He told the delegation which went to meet him that he cannot meet different associations of the employees. He also said that it was difficult to ensure proper behavior of the participants, if he were to meet a large number of faculty members.

The response of the Chairman of the Council caused considerable consternation among the faculty members, when it was discussed in the general body meeting of the Association. The Institute faculty is made up of responsible, distinguished scientists. The comment that they might not behave properly hurt the members. The lack of sympathy for a genuine difficulty also rankled. It was important to protest, but protest in such a way that it did not bring down the dignity of the faculty members and also did not affect the functioning of the Institute. After due deliberations, it was decided that we would boycott the Court lunch, but would participate in the Court meeting. In pursuance of this decision, a majority of Professors and Associate Professors did not turn up for the Court lunch. That had an immediate effect. In the court meeting, J.R.D. Tata, the President, announced a provision for starting construction of quarters. Furthermore, Raja Ramanna, who was then a member of the Council, and a few others arranged a meeting of the faculty members with the members of the Council, the next day. That meeting went very well and marked the beginning of large scale construction of quarters on the campus. The Association was also involved in the formulation of guidelines for allotting quarters.

During the early years of the Association, it was involved in many other initiatives, not as a trade union, but as a body of distinguished scientists interested in improving the functioning of the Institute and maintaining its ethos. I withdrew from the activities of the Association in early 1985, when I became the Chairman of the MBU.

Computational Facilities, Computer Centre, Bioinformatics Centre

I have also been involved from the beginning with the computational facilities of the Institute. Next to MBU, the component of the Institute with which I had maximum interaction was the Computer Centre (later Supercomputer Education and Research Centre, SERC). This was partly on account of enlightened self interest. X-ray crystallography and computational biology require large scale computations. Towards the end of the 1970s, the need for a relook at the Computer Centre was felt. Consequently, S. Ramaseshan, then the Joint Director, appointed a Committee in 1980 with myself as the Chairman, to study the prevailing situation and make recommendations for the improvement of the computer facilities and the Computer Centre. I recall that S.M. Deshpande was also a member of the committee. It was the recommendations of this committee that led to the reorganization of the centre and eventually to the establishment of SERC.

A major landmark in the development of the Computer Centre was the arrival, at the initiation of the Director, of V. Rajaraman, then at IIT Kanpur, as its Head, in the mid-1980s. Rajaraman was considerably senior to me and I looked up to him, still do. My interactions were mainly with N. Balakrishnan (Balki) whom I knew from his student days. He was the Associate Chairman of SERC with Rajaraman and became Chairman on the latter's retirement. For a period of time during the long and distinguished chairmanship of Balki, I was the Divisional Chairman responsible for SERC. Originally, SERC was a Centre directly attached to the Director. It was felt that the centre would get better attention if it was brought under the divisional structure. Among the then Divisional Chairmen, I had the most to do with SERC. I was also then the Convener of the Divisional Chairmen. Therefore, SERC was attached to me. Indeed, I enjoyed working with Balki for the betterment of the Centre. Soon after I became the Associate Director of the Institute in 2000, we created a Division of Information Sciences with Balki as the Chairman. Needless to add, SERC was the centerpiece of the Division. Subsequently, Balki succeeded me as the Associate Director of the Institute. It turns out that we are the only two persons who worked as Associate Directors of IISc.

There was a period when the Computer Centre went through great difficulties on account of the restrictions imposed by USA on the export of technologically advanced items to India. In 1984, the Government of India sanctioned funds for a supercomputer on the occasion of the Platinum Jubilee of the founding of the Institute. During that time, the best known supercomputer, perhaps the only one, was CRAY manufactured in USA. I was, to a limited extent, involved in the discussions for the procurement of CRAY. They would not say point blank, that a CRAY would not be given to us. Instead, impossible conditions were imposed which were difficult for any self-respecting organization to comply with. It was believed that the concerned US authorities discouraged other countries from selling high-end computers to the Institute. This impasse affected our activities adversely. Eventually, the computer technology changed and it became possible to carry out computations even without mainframe supercomputers like CRAY. The stranglehold resulting from export restrictions of US became substantially ineffective. Then of course, US firms became eager to sell their wares to us.

I had a similar experience in relation to computer graphics. By the middle of 1980s, our macromolecular crystallography efforts reached a stage where computer graphics facilities became essential for competitive research in the area. The instrument of choice for this purpose was the one manufactured by Evans and Sutherland, located in USA. On enquiry, they even refused to send us a quotation. Informally, we understood that the machine was probably used in some American battle tanks and supplying one to us would probably pose a security risk to USA! I happened to visit China in 1986. I then learnt that they had no difficulty in supplying an Evans and Sutherland machine to my friend Liang Dong Cai who then headed the Institute of Biophysics in Beijing. Obviously, India could be pressurized while China could not be! In the meantime, new Silicon Graphics machines became available and one of my old Oxford colleagues was associated with their development. Eventually, we could procure a Silicon Graphics machine. Over the years, graphics facilities became common place and are now even part of low-end PCs.

Another computational effort I have been involved in at the Institute had to do with Bioinformatics. As part of an initiative of the Department of Biotechnology (DBT), Viswamitra took the lead in establishing a Distributed Bioinformatics Centre attached to the Physics

Department. Viswamitra was helped by Ramakumar, who was then a faculty member of the department. An important role in running the Centre was played by Margaret Biswas who took her Ph.D. earlier under V.S.R. Rao. The Centre came under my tutelage after Viswamitra formally retired in 1993. By then, I had also become the Chairman of the Division of Biological Sciences. Margaret left the Institute soon afterwards and the new recruits to the Centre were K. Sekar and Nagasuma Chandra who had taken their doctorates from Madras University and Bristol University respectively, before working as post-doctoral fellows in my laboratory. Eventually, the Centre was shifted to the Biology Division and subsequently brought under SERC. That was where things stood when I formally retired as Associate Director in 2004.

Concerted efforts of crystallographers

Originally, a crystallography group existed only in the Physics Department. The group was led by M.A. Viswamitra from the 1960s. In the second half of the 1960s, H. Manohar initiated crystallography activities in the Department of Inorganic and Physical Chemistry (IPC). He was perhaps the first person, certainly among the first few, to start crystallographic work in a chemistry department in India. In 1971, K. Venkatesan joined the Organic Chemistry (OC) Department to initiate chemical crystallography in that department. Venkatesan took his Ph.D. in the 1950s under the supervision of S. Ramaseshan in the Physics Department. He did his post-doctoral work with Jack Dunitz in Zurich and with Dorothy Hodgkin in Oxford. His work in Oxford using anomalous dispersion has been much acclaimed. Venkatesan then joined GNR's department in Chennai as a faculty member. It was Dorothy who recommended his name to K. Banerjee, the then Head of the Organic Chemistry Department, for a position. I came back to India in 1971 and secured a regular faculty position at MBU in 1974.

Thus, by the mid-1970s, we were four crystallographers at the Institute; Viswamitra in Physics, Manohar in IPC, Venkatesan in OC and myself in MBU. The first three were nearly in the same age group and I was the baby of the team. Happily, we all worked in concert in relation to common facilities and teaching programmes. In 1974, the Institute acquired a four circle diffractometer for X-ray intensity data collection, the first Indian institution to do so. All the four of us used the machine in an equitable manner. Those who were employed to look after the machine included K.I. Varughese, now a senior scientist in the USA, Ravi Archarya, now a Professor at the University of Bath, and N.C. Shivaprakash who is now a senior faculty member at the Institute. Over the years, Shivaprakash served the Institute and the community with great distinction.

Manohar, Venkatesan and myself organized common teaching programmes. Many of the courses were attended by non-crystallographer chemists as well. In later years, I used to be pleasantly surprised when senior chemists in different institutions came and told me that I have taught them! The students from the four groups also worked together, especially in implementation and development of software. By the second half of the 1980s, Viswamitra and Manohar had their own diffractometers and the main responsibility of looking after the old machine fell on me, although my efforts had by then begun to be focused on macromolecular crystallography facilities (see later). Many old students joined as faculty members, S. Ramakumar, T.P. Seshadri and N. Shamala in Physics; M.R.N. Murthy and K. Suguna in MBU; and T.N. Guru Row in the Solid State and Structural Chemistry Unit (SSCU). The work of many of them was primarily concerned with macromolecular crystallography. Eventually, the responsibility for organizational efforts in relation to small molecular crystallography fell on the shoulders of Guru Row. Unfortunately, small molecular crystallography, particularly chemical crystallography, is now in the process of disappearing from the Institute. In particular, structural crystallography is now conspicuous by its absence in the Physics Department which was a cradle of a substantial part of Indian crystallography. Happily, the Institute continues to be a major centre of macromolecular crystallography. As we shall see later, much of macromolecular crystallography in India radiated from the Institute.

Deep in Institute administration

Research at the Institute is carried out primarily using competitive grants obtained through research projects sponsored by different agencies. The Institute provides infrastructure and wonderful students, but only very little by way of research funds. Funds that faculty members bring in through research schemes or projects are more than an order of magnitude higher compared to those provided internally. To start with, funds obtained through sponsored projects used to be handled by what was called the scheme section in the central office. It was important that this section functioned smoothly. One of my earliest involvement with Institute administration was in relation to the handling of sponsored projects. I was almost continuously involved with this effort in terms of policy formulation and administrative details. Eventually, a Centre for Sponsored Schemes and Projects (CSSP) was established in the 1990s under the leadership of H.S. Mukunda. Mukunda and the officer in charge R. Mohan Das, honed the Centre into a wonderful instrument in the service of the research community at the Institute. I worked closely with the Centre, particularly when I was Divisional Chairman and Associate Director. Mukunda's outstanding contributions in rocket propulsion and power generation using solid waste are very well known. Mohan Das rose to become the Registrar of the Institute and served the Centre as an Adviser for several years after formal retirement.

Another area in which I got involved soon after I became the Chairman of MBU, had to do with purchase. There were several bottlenecks in purchase procedures. I complained about them in a meeting of departmental Chairmen with the

Director. C.N.R. Rao, the then Director, asked me in turn if I could streamline the procedure if he gave me full powers to do so. I undertook this responsibility. I worked closely with N.S. Prahalad, the then Purchase Officer. I became aware of his difficulties. In particular, it was important to set right the interface between Purchase and Finance/ Accounts. That led to my involvement with Finance/ Accounts as well. The experience I gained in the process stood me in good stead in my later work as the Associate Director and also when dealing with financial issues at the national level.

Until the late 1970s, the Institute was free from employee problems. A great deal of informality prevailed in the relation between the Institute and the employees. The growth of the Institute and therefore its workforce meant that this relationship could not be regulated on an informal basis. By the late 1970s, an active Employees Association came into being. The number of sponsored projects increased substantially in the 1980s and a large number of employees were appointed in the projects. Some of them were provided with salaries with grades and designations normally given to permanent employees of the Institute. The large temporary workforce in sponsored projects was an issue we had not learnt to deal with. The Institute was obliged to regularize the jobs of a large number of project staff. This meant that the number of supporting staff on the rolls of the Institute was larger than what was desirable. Furthermore, the Institute appears to have been complacent in relation to the genuine grievances and concerns of the employees. Eventually, agitation of employees became a norm in the campus. I was drawn into dealing with the agitating employees. A formal negotiating committee was set up. I was a member of that committee when A. Sridharan was its Chairman. Subsequently, I followed him as the Chairman of the committee.

To start with, SC/ST employees were part of the Employees Association. Later, they parted with the parent body and formed their own Association. The parent body and the SC/ST Association were often at loggerheads and the administration was caught in the middle. The intervention of the SC/ST Commission added a new dimension to the problem. One major issue could be resolved only through the intervention of the Court. All put together, the atmosphere at the Institute was often tense and unpleasant. Attempts to address problems piecemeal created several anomalies which were difficult to reconcile. Many senior faculty colleagues, notably A. Sridharan, contributed to sorting out the issues and solving them. Only by 2000, most of the issues could be reasonably settled. I recall that my last act before assuming the Associate Directorship of the Institute that year, was to sign the final agreement with the Employees Association, as the Chairman of the negotiating committee.

The construction of a large number of dwelling units within the campus and at a nearby location brought its own problems in its wake. Housing is a gut issue and everyone has his/her own preferences. It was difficult to address them within the framework of accepted rules. There were often endless discussions on the formulation of rules, including those concerned with reservation for SC/ST employees in house allotment. All these issues were primarily dealt with by the House Allotment Committee. Like some other Professors, I also chaired this Committee for a few years. With the periodic addition of dwelling units and a depletion of the number of employees, the situation eased considerably.

Involvement with housing naturally led to that with the Estate Office dealing with works and maintenance. To cut the long story short, I have had occasion to deal with almost all aspects of Institute administration. I also worked in several Institute Committees. In the meantime, I also worked for a few years as the Editor of the Journal of the Indian Institute of Science. In this context, two important activities I recall were in relation to producing special volumes to commemorate the birth centenary of C.V. Raman in 1988 and that of Jawaharlal Nehru in 1989. I had the help of N. Mukunda and T.V. Ramakrishnan in these efforts.

The one with whom I worked most closely in the Institute administration was A. Sridharan, a Professor in Civil Engineering and like me, an old student of the Institute. He rose to become a Divisional Chairman and Deputy Director of the Institute. He was involved in almost all aspects of Institute administration. We worked closely together on many occasions. He is a few years senior to me and we have different personalities. However, those did not come in the way of perfect rapport between us. We have been close friends and continue to be so. I have worked with several others on administrative matters and the names of Balki, R. Kumar and H.S. Mukunda come to mind. Then of course, there are Directors and Divisional Chairmen and Deans with whom I worked. I was also fortunate to have had perfect relationships with officers.

I recall that P.R. Prabhu was the Registrar of the Institute when I came back from Oxford in 1971. He was succeeded by T. Nanjunda Rao. I had pleasant interactions with him. After his premature death, H.V. Venkataramaiah became the Registrar. By then, my serious involvement with administration had begun and I had much to do with him. I was very close to P.S. Venkateswaran who succeeded Venkataramaiah. I worked closely with B.R. Srinivasa Murthy and B.V. Ramakrishna who assumed the office subsequently. Uday Balakrishnan who was the Registrar when I was the Associate Director, was to a substantial extent my appointee. My relation with Uday went well beyond the professional domain. I have fond memories of other officers like G. Vijayaraghavan and B.A.G. Sharma, successive Financial Controllers and A.L. Narasimhan, B.K. Subburaman, R. Mohan Das, M.S. Venkatesh, K. Panneerselvam, A.V. Subbanna, S. Rajagopalan, M. Krishna Murthy, N.V. Raghavan, M.R. Chandrasekhar, P. Manivannan, G. Nagesh, B.N. Balaji and many others. My involvement with administration received added legitimacy when I became the Divisional Chairman and subsequently

Associate Director. I recall the protective support of my secretary G. Lalitha when I was the Associate Director. During most of my time in the Central office, C.N. Chayapathy was the secretary of the Registrar. His help to me was also invaluable.

Divisional Chairman

To start with, the biology departments were part of the Division of Chemical and Biological Sciences. The first Chairman of this Division was A.R. Vasudeva Murthy followed by H.R. Cama, H. Sharath Chandra and T.R. Kasturi. When the divisional structure was introduced, there were three biology departments, Department of Biochemistry (BC), Microbiology and Cell Biology Laboratory (MCBL) which was later rechristened as a department, and the Molecular Biophysics Unit (MBU). Later, the Centre of Ecological Sciences (CES) was established by Madhav Gadgil. Madhav's was an impressive presence in the Institute. His wife Sulochana, also on the Institute faculty, made important contributions in the field of atmospheric sciences. I have always admired the Gadgil couple. I felt that I have much in common with Madhav, although we worked at two extremities of biology. There were no formal interactions among the biology departments except through the Division of Chemical and Biological Sciences. BC, MCBL and MBU were brought together to conduct a common programme, with the involvement of the National Biotechnology Board (NBTB) which was established under DST in 1983. NBTB laid great emphasis on teaching and they wanted to bring the Institute into their teaching programme. The Institute was not happy to start formal teaching programmes in the Science Faculty. After considerable discussion, it was decided in the mid-1980s to start an NBTB post-doctoral programme involving BC, MCBL and MBU. The programme was piloted by V. Sasisekaran who was then the Dean of the Science Faculty. The admission to the programme in its first year was managed by G. Padmanaban. I carried out this responsibility in the second year. In retrospect, this appears interesting in view of our future career trajectories.

The Division of Biological Sciences was started in 1987 with Sasisekaran as the first Chairman, by bringing together the three departments, one centre, the Central Animal Facility (CAF) and the Primate Research Laboratory (PRL) under one umbrella. The NBTB post-doctoral programme now came under the Biology Division. The programme continued after NBTB was converted into the full-fledged Department of Biotechnology (DBT). Much later, it was expanded into a national programme with the Institute having the responsibility to conduct it.

G. Padmanaban succeeded Sasisekaran as the Divisional Chairman in the late 1980s. On his initiative, among other things, the support of DBT to the Institute increased substantially. S. Ramachandran, the first Secretary of the DBT and his colleagues in the Department, were also very supportive of the relation between the DBT and the Institute. The enhanced support was formalized in the form of an Umbrella Programme in 1990. The post-doctoral programme and the Bioinformatics Centre were also brought under the framework of the overall programme. I was deeply involved in formulating and conducting the Umbrella Programme, as Chairman of MBU. In addition, I also undertook the responsibility of establishing an Interactive Graphics Facility under the programme. It was decided that the Facility would be located in the Bioinformatics Centre and would be operated from MBU by me, as an individual and not as the Chairman of MBU. This was done at the instance of the Director, C.N.R. Rao, to ensure that the Bioinformatics Centre, then attached to the Physics Department, had a relationship with the Biology Division through the Graphics Facility.

I succeeded Padmanaban as the Divisional Chairman in March, 1993 when he became the Deputy Director of the Institute. The other Divisional Chairmen at that time were A. Sridharan (Mechanical Sciences), M.A.L. Thathachar (Electrical Sciences), K.J. Rao (Chemical Sciences) and N. Kumar (Physical and Mathematical Sciences). Kumar left the Institute within a year to assume the Directorship of the Raman Research Institute (RRI). He was succeeded by S.V. Subramanyam. Sridharan, the senior most among us, was the Convener of the Divisional Chairmen. The Convener chaired the weekly meetings of Divisional Chairmen and was responsible for the Divisional Office. In the absence of an Associate or Deputy to the Director, he was hierarchically number two to the Director, in practical terms.

Divisional Chairmen have a crucial role in running the Institute. They are deeply involved in the appointment, assessment and promotion of faculty members. They have a decisive role in temporary appointments including those of project personnel and in purchase processes. They almost constitute a Cabinet of the Director. During our time, we used to sit in small cubicles around the Divisional Office. I recall N. Mukunda, who himself was a Divisional Chairman earlier, mentioning that those cubicles have the maximum concentration of authority and power in the Institute!

In August 1994, Padmanaban took over the Directorship of the Institute. Sridharan was appointed as the Deputy Director in his place. Sridharan was succeeded by K.J. Rao as the Convener of Divisional Chairmen. I succeeded to that office towards the end of 1996. After a few changes, the Divisional Chairmen when I left the Divisional Office in early 2000, were S.S. Krishnamurthy (Chemical Sciences), Ajay Sood (Physics and Mathematics), M.L. Munjal (Mechanical Sciences) and Y.V. Venkatesh (Electrical Sciences). I was succeeded by P. Balaram as Chairman of the Biology Division. During my tenure as the Divisional Chairman, the one who was closest to me in the Divisional Office was S. Ranganathan, who was the Chairman of the Mechanical Sciences Division during 1994-98.

I have already referred to the rapport between Sridharan and myself in administrative and policy matters. This association continued during his tenure as Deputy Director and Advisor till early

2000. During most of this period, I was the Convener of the Divisional Chairmen. Therefore, it was important that we worked together.

During the early years of my Chairmanship, the Biology Division was made up of BC, MCB, MBU, CES, CAF, PRL, in addition to three small centres, viz., the Centre for Genetic Engineering (CGE), Centre for Reproductive Biology and Molecular Endocrinology (CRBME) and Developmental Biology and Genetics Laboratory (DBGL). CGE, CRBME and DBGL were individually too small to be viable. Among the departments, units and centres, MBU and CES had distinctly different mandates. All the remaining outfits worked in the broad area of biochemistry and molecular biology. Thus, a reorganization, especially in relation to the three small centres, was called for. Padmanaban, the Director, fully concurred with this view. Eventually, CGE was merged with MCB. H. Sharat Chandra and K.P. Gopinathan, the Chairmen of CGE and MCB respectively, were very helpful in effecting this merger. The merged department was initially led by Gopinathan who was succeeded by Rabindranath Nayak. Gopinathan has been a lifelong friend. I knew Nayak for a shorter period. However, we became very close to each other. His help was invaluable when I was the Divisional Chairman. After a great deal of discussion, it was decided to merge CRBME and DBGL into one. Naming the merged department caused problems. I was in favour of calling the new entity the Department of Reproductive and Developmental Biology. However, in view of the sensitivities of different colleagues, it was given the somewhat unwieldy name of Molecular Reproduction, Development and Genetics (MRDG). MRDG consolidated into a coherent unit under the successive leaderships at A.J. Rao and V. Nanjundaiah.

In addition to the normal responsibilities of a Divisional Chairman, the Chairman of the Biology Division also coordinated some interdepartmental efforts. The most important one among them was concerned with the support from DBT. As indicated earlier, the first such effort was the post-doctoral programme initiated by Sasisekharan. As Divisional Chairman, Padmanaban organized an Umbrella Programme which involved most, but not all, faculty members of the Division. We then decided to have a comprehensive programme on the conclusion of the Umbrella Programme, which came to be described as “Program Support in High Priority Areas in Biology”. In the run-up to the programme, it was necessary to identify high priority areas which would encompass the whole divisional faculty. Till the advent of the DBT support, most of the research used to be carried out using comparatively small grants secured by individual faculty members. Perhaps the only exceptions then were the macromolecular X-ray facility at MBU under my leadership and the DBT support for CGE. This meant that major instruments, which could not be accommodated in small grants, were not available in the Division, except in the case of X-rays.

It was important to seriously address the twin issues of identifying areas of support and the procurement of major instruments. To this end, I requested all the members of the Division to provide me with a short write-up of the research programme they envisaged and the facilities they required to execute it. On the basis of the responses received and subsequent discussions, three high priority areas were identified: Infectious Diseases; Drug and Molecular Design; and Gene Targeting, Genetic Disorders and Genetic Diversity. Under each head, a group of faculty members were assigned with a Convener. The major facilities proposed and subsequently acquired were Fluorescence Activated Cell Sorter, Confocal Microscope, Mass Spectrometer, Biosensor, Autoradiography System and a Protein Peptide Sequencer. A small committee with a Convener was entrusted with the responsibility of running each facility. The Bioinformatics Centre, Graphics Facility and the post-doctoral programme were also brought under the ambit of Programme Support. The entire programme was monitored and supervised by a committee headed by the Divisional Chairman. Every year, an external Apex Committee consisting of distinguished scientists reviewed the work. During my time, the Apex Committee was chaired successively by B.K. Bachhawat and P.N. Tandon. That phase of programme support ran from 1997 to 2002. By and large, the same organizational structure was adopted in the subsequent phases as well. On behalf of the DBT, S.R. Rao, an able officer, was most of the time the Secretary of the Apex Committee.

Another important effort that I was involved in as the Divisional Chairman was on Technology Development Mission (TDM). TDM was operated by the Ministry of Human Resources Development (MHRD), with the involvement of all the IITs and IISc. A few areas were identified under TDM. One of them was Biotechnology. The lead institution for the Biotechnology Mission was IISc. The other participating institutions in the Biotechnology Mission were IIT Delhi and IIT Kharagpur. I was the National Coordinator of the Biotechnology Mission. I recall attending a meeting on TDM at the Planning Commission head-quarters chaired by Pranab Mukherjee who was then the Commerce Minister at the Centre. The basic features of the Mission were enunciated in that meeting. Each project under the Mission should have an industrial partner. Seventy five percent of the budget would be provided by the Government. The remaining 25% needs to be borne by the industrial partner, 15% in kind and 10% in cash. If the project succeeds, the industrial partner has the first right of refusal in technology transfer. The terms of technology transfer had to be worked out separately in each individual project. The participants in TDM were very enthusiastic. The only discouraging feature was the tardiness in releasing funds by MHRD. I recall sharply taking on the Secretaries on the matter in an Expenditure Finance Committee (EFC) meeting in Delhi. Many of the projects under the TDM were successful. Apart from other things, it provided me with an opportunity to interact closely with IIT colleagues and also enhanced my understanding of industrial interactions. In addition to that of Biotechnology, a few other TDM's were operative in the Institute. B.S. Sonde and M.V. Krishna Murthy were involved in coordinating the efforts under the several TDM's at the Institute. I worked closely with them. One person whom I came to know well through work in TDM is Rintu Banerjee of IIT Kharagpur.

The Society for Innovation and Development (SID) established by the Institute in 1991, was at its infancy during the period when I was the Divisional Chairman. The Centre for Scientific and Industrial Consultancy (CSIC), established in 1975, was till then the only formal vehicle for industrial interaction. SID, an autonomous body with umblical cord to the Institute, was meant for longer term interactions at a higher level between the Institute and industry. In its formative years, SID was ably led with dedication by H.P. Khincha. I was also deeply involved in discussions aimed at shaping the character of SID and its relation with CSIC. Between them, SID and CSIC continued to play distinctly different but related roles in the engagement of the Institute with the outside world.

Padmanaban, like many others, was concerned with the inadequate engagement of the Institute with undergraduate education. After a great deal of discussion, a programme was devised in which selected undergraduate students could work in the Institute for short periods of time. It is this programme which eventually led to the now well established Kishore Vaigyanik Protsahan Yojana (KVPY) which has a national reach.

An important event during the period when I was the Convener of Divisional Chairmen, which I recall vividly is the celebration of the Golden Jubilee of Indian Independence. It was decided that the main science-related event as part of the celebration would be held at the Institute. A number of well-planned functions were organized at the Institute from 28 February to 3 March in 1997. The main responsibility for organizing and coordinating these functions under the guidance of the Director rested with me. I was ably helped in these efforts by S. Ranganathan. The Institute orchestrated the whole initiative as one person to make the event successful. The event consisted of several symposia and lectures involving almost all the senior scientists of the country and cultural programmes. The highlights of the events, in my view, were the open-day when several tens of thousands of students visited the Institute and the visit of the Prime Minister.

The Prime Minister then was Deve Gowda. After visits to different departments and discussions with senior members of the Institute, he addressed the faculty and students in the main hall of the Tata Auditorium. One was not sure what to expect from the Prime Minister, as Deve Gowda had not had much interactions with the scientific community. In the event, he charmed the audience with simplicity and a straight forward approach. He said that he had with him a long speech prepared by his office. However, instead of reading from it, he preferred to speak ex-tempore. He started by saying that he was a Prime Minister by accident. The coalition partners wanted Jyoti Basu to be the PM. However, his party would not allow it. That is how as an accident the mantle fell on his (Deve Gowda's) shoulders. Thus, he continued, 'one can become a Prime Minister by accident. But one cannot become an Abdul Kalam (who was in the audience) by accident!'. Through these observations he completely won over the audience. He then proceeded to deal with policy issues. There was another implication for his opening remarks. The Office of the Principal Scientific Advisor to the government was then vacant. There was speculation as to whom the government would choose for this post. The Prime Minister's laudatory reference to Abdul Kalam provided a pointer. Abdul Kalam was appointed in the post soon afterwards. The only other occasion when I interacted with Deve Gowda was when I received the FICCI award at a function in New Delhi, a few months later.

A hiccup, Associate Directorship

As Padmanaban was due to retire on July 31, 1998, speculations and discussions on the next Director commenced in 1997. Many people in the Institute and elsewhere expected me to succeed Padmanaban. However, that did not happen. In fact, no professor of the Institute was appointed as the Director. In the process of appointment, there was also some departure from the practices normally followed. The Institute community had a perception as to why this happened. After two decades, there is now no point in dilating on the issue. The decision on the Directorship shocked many, inside and outside the Institute. I, however, decided to take it in my stride. I recall all Divisional Chairmen discussing the issue at dinner on the day on which the decision became known. It was clear to us that the institution was more important than individuals. There was resentment in our minds, but we decided to go on with our responsibilities as if nothing had happened.

I knew the new incumbent Goverdhan Mehta reasonably well. We had worked together in committees including the Council of the Indian Academy of Sciences. He had impressed me as a distinguished chemist and an upright person. Therefore, at a personal level, I had no difficulty in dealing with him, which I had to as the Convener of Divisional Chairmen. Goverdhan returned my warmth in ample measure.

The Institute was in no way unknown to Goverdhan. However, naturally he was not intimately familiar with its working. In the initial months of his Directorship, one of my chores was to help him familiarize himself with the workings of the Institute. In early 1999, about six months after the change of guard, I had a long discussion with him. I told Goverdhan that I felt that I owed to the Institute and to him to work for a few months in the Central Office after he assumed the Directorship. Now it was time for him to choose his team. Goverdhan's reply was that he was looking for the Institute team and not his team. Furthermore, he wanted me to accept the vacant position of Deputy Director. I sought time to discuss with my colleagues and come to a decision.

I had extensive discussions with colleagues and friends on the offer of Deputy Directorship. Most of them felt that I should not accept the post in view of what happened in the selection of the Director. They felt that I should accept only a position near-equal to the Director such as Additional Director, Joint Director or Associate Director. I conveyed this message to Goverdhan who took up the matter with the Governing Council. The creation of a new post required an amendment of the rules and regulations of the Institute. The request for such an amendment needs to be processed through MHRD and it should be approved by the Visitor who is the President of India. The Council in its wisdom initiated the amendment to create (or to upgrade the position of Deputy Director into) the position of Associate Director. I understand that the proposal got stuck at the President's office. Apparently, they were concerned about the creation of a position near-equal to that of the Director. A distinguished younger colleague of mine, who had extensive connections with different segments of the Government of India, became aware of it. He advised the concerned person in the office, under intimation to me, that the PSA who was then Abdul Kalam might be contacted, in case of doubt. Abdul Kalam knew the situation well and presumably his intervention was positive. Eventually, I took over as Associate Director of the Institute on March 23, 2000.

I was touched by the keenness of Goverdhan to retain me as his colleague in Institute administration. I recall a particular conversation I had with him at the time of my assuming the new office. I said that the Associate Director should not be an alternative centre of power or an additional step in the hierarchy. The offices of the Director and the Associate Director should work together as if they are one and the same. We followed this guideline throughout the period of more than four years when we worked together. When there was a difference of opinion between the two, nobody except us knew about it. I performed, with full concurrence of Goverdhan, many of the responsibilities of the Director. In his absence or when he was not available, I took decisions independently on matters small and big. However, when I had the smallest inkling that Goverdhan might have a different view, I deferred the decision. Contrary to conventional wisdom on issues related to leadership positions, we worked closely together as friends without ever undermining each other.

On the lighter side, there was an issue of how to abbreviate "Associate Director" in internal notes. I said that any abbreviation other than "Ass. Director" was acceptable to me. Eventually the abbreviation "AD" prevailed. The Associate Director was supported by an efficient secretariat headed by G. Lalitha, whom I have already referred to. Lalitha was deeply committed to the job and looked after me very well.

The March meeting of the Promotion and Assessment Committee (PAC), Finance Committee and the Governing Council took place soon after I assumed the Associate Directorship. I was already a participant in the PAC for more than seven years as Divisional Chairman. I was attending the Finance Committee and the Council meetings for the first time. The Finance Committee and the PAC meetings take place before the meeting of the Council. The recommendations of the first two are then considered by the Council and decisions taken. Another meeting which precedes the Council meeting is that of the Investment Committee which I chaired after I became the Associate Director. Yet another meeting, the recommendations of which go to the Council, is that of the Building and Works Committee, which again most often I chaired after March 2000. The Chairman of the Council then was Raja Ramanna. He chaired the meeting of PAC and Finance Committee as well. The Council was made of eminent persons, representatives of national science agencies and members of parliament.

The March meeting took place in the middle of a financial crisis at the Institute. Sanctioned funds had not been released by MHRD. The Financial Controller of the Institute was scheduled to visit MHRD in this respect. Ramanna suggested that I should go to Delhi, accompanied by Financial Controller, to impress upon the MHRD the gravity of the situation. Accordingly, I visited MHRD on March 28. I have had close contacts with various science departments. However, this was my first important visit to MHRD. I was not very sure how to manage it. We met the Secretary, M.K. Kaw, and all the concerned officers. I was overwhelmed by their cordiality and respect for the Institute. Immediate action followed our visit to MHRD. This incident confirmed that the problem is with the system of bureaucracy and not with bureaucrats as individuals. As Rajan Gurukkal, a well-known historian and former Vice-Chancellor of Mahatma Gandhi University once observed, the financial bureaucracy during the colonial period was designed to spend as little money as possible on Indians. We have not yet substantially modified the system. Thus, in practice, the primary role of financial bureaucracy continues to be raising objections and thereby delaying release of funds, rather than facilitating expenditure and utilization of funds.

By mutual agreement involving Goverdhan and myself, I took the primary responsibility for financial and related matters. This was true in relation to the interface with employees. The roles of Director/Associate Director at the Institute are multifarious. They include involvement with academic programmes, giving inaugural and valedictory addresses, receiving distinguished visitors, chairing innumerable committees, looking after the campus and associated establishments like the Health Centre and the Central School and so on. Goverdhan and I shared these responsibilities without any friction.

The Institute has a robust system of governance based on a substantial degree of participatory democracy and functional autonomy of its different constituents. Most of the important decisions are taken by faculty members or committees made up of them. In the absence of proper coordination and on account of inadequate appreciation of rules and procedures, anomalies often occur. Therefore, I used to insist that officers should be associated with each committee to ensure administrative soundness, without compromising the supremacy of the faculty in decision making processes. On the other side of the coin, the bureaucracy has an inherent tendency to become slow and obstructionist. Therefore, it is important that faculty members in administrative positions are familiar with rules and regulations. Over the decades, I became fairly proficient in administrative rules and procedures. That was of help in streamlining the administration at all levels. Government rules cannot be broken, but they can be bent. One should know the rules well for bending them. I have bent rules with impunity!

I also tried to pay particular attention to the weaker segments of the Institute. Academic departments are normally led by powerful colleagues who are capable of protecting and furthering the departmental interests. This is not true with non-academic outfits. I used to make special efforts to help them. I paid particular attention to the Health Centre and the Central School. Figuratively speaking, I had given a blank cheque to the then Chief Medical Officer, P.H. Prasad, in relation to his requirements. The faculty of the Institute are always treated with respect. We get the cream of young India as students. By and large, they are well protected. The powerful union protects the interests of the employees. The officers, particularly the junior ones, are neglected. I used to take special care to see that they are looked after well, at the same time, insisting that they deliver. Another disadvantageous section at the Institute comprise scientific officers at different levels. They again received my special attention.

I, like many others, have mixed feelings about voluntary retirement. However, we came to the conclusion that voluntary retirement was appropriate at that stage for the Institute. For reasons indicated earlier, the strength of supporting staff (employees) at the Institute, rose at one stage to 1800. This was excessive and unhealthy. The Voluntary Retirement Scheme was executed at more than one stage, very efficiently by the then Registrar, Uday Balakrishnan, with the full support of the Director, Associate Director and others concerned. In fact, most employees heartily welcomed the generous Voluntary Retirement Scheme and they availed of it in large numbers. My efforts all along has been to ensure that the employees got all the benefits that they deserved. At the same time, it was also important to make sure that the Unions did not over reach themselves. On the whole, I had, and continue to have, perfect rapport with the employees.

Housing of faculty and students continued to be a serious problem. During the period when Goverdhan and I were at the helm of affairs, the number of faculty housing units was enhanced substantially. There was considerable pressure, including from within the Council, to increase our intake of Ph.D. students. In this respect, the most severe constraint was hostel accommodation. In order to overcome this problem, we constructed a new hostel block which could accommodate almost 1000 students. This was an effort in which I was personally involved in.

During our time, the annual (non-plan) grant to the Institute from MHRD was around Rs 80 crores, of which only about 2 crores were set apart for research (equipment, consumables, contingencies etc.). On the other hand, competitive grants obtained by faculty members, individually and collectively, was to the tune of Rs. 50 crores, excluding accruals through SID and CSIC. Thus, assured support from the Institute for research was a very small fraction of the amount spent by the faculty on research. This was an unsatisfactory situation. The granting agencies have been extraordinarily considerate to the Institute, yet obtaining grants from them sometimes involved tailoring research programmes to suit their requirements. It was also often difficult to undertake risky projects. It was impossible to rectify the situation in a short span of time. However, through a sustained campaign I could persuade the Council and the MHRD to raise the provision for research from Rs 2 crores to Rs 3 crores. Ideally, I believe that internal institutional support should match the amount raised from competitive grants.

In the middle of multifarious responsibilities involving administration, I ensured that research and associated academic activities did not suffer. Much of the major results on protein structures emanated from our lab during the 11 odd years when I was successively Divisional Chairman and Associate Director. Earlier, our work on small biomolecules peaked during the seven odd years when I was the Chairman of MBU. Scientific research and mentoring of Ph.D. students, post-docs and other young scientists, always occupied the top slot in my order of priorities. The same was true when the centre of gravity of my official responsibilities shifted to Delhi after my formal retirement. In fact, our major programme of mycobacterial, mainly TB, proteins took shape when I was the Associate Director of the Institute. It was during this period that I orchestrated a major national campaign for the structural genomics of microbial pathogens. During this period, I also took a major initiative in relation to synchrotron facilities.

What makes the Institute tick?*

After formal retirement as Associate Director on July 31, 2004, I continued in the Institute successively as Distinguished Biotechnologist Professor (DBT), Homi Bhabha Professor (Department of Atomic Energy (DAE)), Albert Einstein Professor (Indian National Science

* Much of this section has been reproduced from a Current Science article of mine (*Curr. Sci.* **115**, 1031-1032, 2018)

Academy (INSA)) and Platinum Jubilee Senior Scientist (National Academy of Sciences, India (NASI)). During the first five years immediately after retirement, I was also Honorary Professor of the Institute. From the time I joined as a student in 1963, I have been associated with the Institute almost continuously for well over half a century in different capacities. This association has provided me with insights into the character and working of the Institute.

When the Institute was founded in 1909 through the efforts of J.N. Tata, it was the second scientific institution to be established in India by Indians. The first was the Indian Association for the Cultivation of Science (IACS) founded in Calcutta by Mahendralal Sarkar in 1876. However, IACS was somewhat dormant until C.V. Raman got associated with it in the early years of the 20th century. J.N. Tata initiated his efforts to start a science institution in the last decade of the 19th century. The efforts did not fructify for a long time partly on account of the apathy of the British rulers. Eventually, the Indian Institute of Science was established in 1909 on the land (approximately 400 acres) donated by the then Maharaja of Mysore. The 110 years old Institute is celebrated as the most eminent scientific institution in the country. How did this come about?

The ambience of an institution is an undefinable quantity. It is made up several elements such as excellence, mutual respect of its members, freedom to pursue intellectual efforts and so on. "The only other institution in which I have worked is the University of Oxford. As far as ambience is concerned, but not in terms of accomplishments, I do not find any difference between the two institutions. Ambience is built and preserved over long periods of time. Many institutions in India have a tendency to start with a flourish and then decay over the years. IISc is now more than 100 years old. It is remarkable that it still remains vibrant.

"One prerequisite for eminence of an institution of higher education and research is autonomy. Autonomy is of course within the overall framework of Government rules and regulations, and should go along with accountability in relation to the stated or perceived goal and financial management. IISc has been fortunate to have been granted substantial autonomy in letter and spirit. The Governing Council of the Institute has members of parliament as its members. I, like many others, have held the view that the role of representatives of people in relation to academic institutions is to help in formulating overall policy directions and sensitizing the organization to national and societal needs. It is not desirable for them to indulge in micro management. The members of parliament who served on the Council of the Institute have by and large followed this overall approach. This has been largely true of the representatives of the Government as well. The relation between the Council and the Senate, the highest internal body of the Institute, has also been cordial. It is only very rarely that the Council declines to accept a recommendation of the

Senate. Even on the rare occasions when it did, the communications to that effect were couched in very polite language.

"Autonomy percolates through the entire organization. The departments enjoy substantial functional autonomy. Within each department, individual faculty members are to a great extent autonomous. In fact, a faculty member and his/her group constitute the basic autonomous unit of the Institute. Unlike many other smaller institutions in the country, IISc is not Director-centric. The Director and other leaders are important, but the institution runs as a system. In fact, autonomy is most effective when it is accompanied by internal democracy. Decision making should be substantially a collective participatory process, without it degenerating into anarchy. In this respect also, the system has worked reasonably successfully. Participatory democracy, even within an overall framework, is sometimes inconvenient. However, in the long run, it is effective. As Satish Dhawan used to say 'we are perhaps a little ponderous, but ultimately get there'.

"Appointments and admissions based on merit, made after due diligence, are important for maintaining the health of the institutions. At IISc, only the Director is appointed without the involvement of the Institute faculty including the outgoing Director. Therefore, this appointment is susceptible to external influences. The selection committees for the appointment of faculty and support staff are chaired by the Director or his/her nominee. Subjective factors sometimes come into play, but by and large the system has served well. Faculty appointments are usually preceded by discussions at different levels to eliminate mishaps. Admission of students is also made through an elaborate process to ensure that best candidates are chosen. On the whole, the students of the Institute belong to the cream of young India.

"Bureaucracy is a bane of science in India (I have complaints only about bureaucracy as a system and not about individual bureaucrats, many of whom are splendid persons). There is considerable flexibility within the rules and regulations of the Government. The effort in institutions of eminence should be to interpret the rules and regulations in the most liberal manner. For this to happen, it is important that academics occupying administrative positions are well versed in appropriate rules and regulations. Bureaucracy cannot be wished away, but in autonomous institutions with internal democracy, it can be honed to facilitate and not obstruct legitimate activities.

"As in the case of liberty, the price of autonomy, internal democracy, emphasis on merit, absence of rigid bureaucracy, etc. is eternal vigilance. Distortions of and deviations from these attributes can, and indeed do, occur in the best of institutions. They have to be continuously fought against. This is particularly important in view of the recent tendency to erode the positive attributes, particularly, autonomy. The traditions and quality of many of our institutions of higher learning and research, are worth fighting for".

7

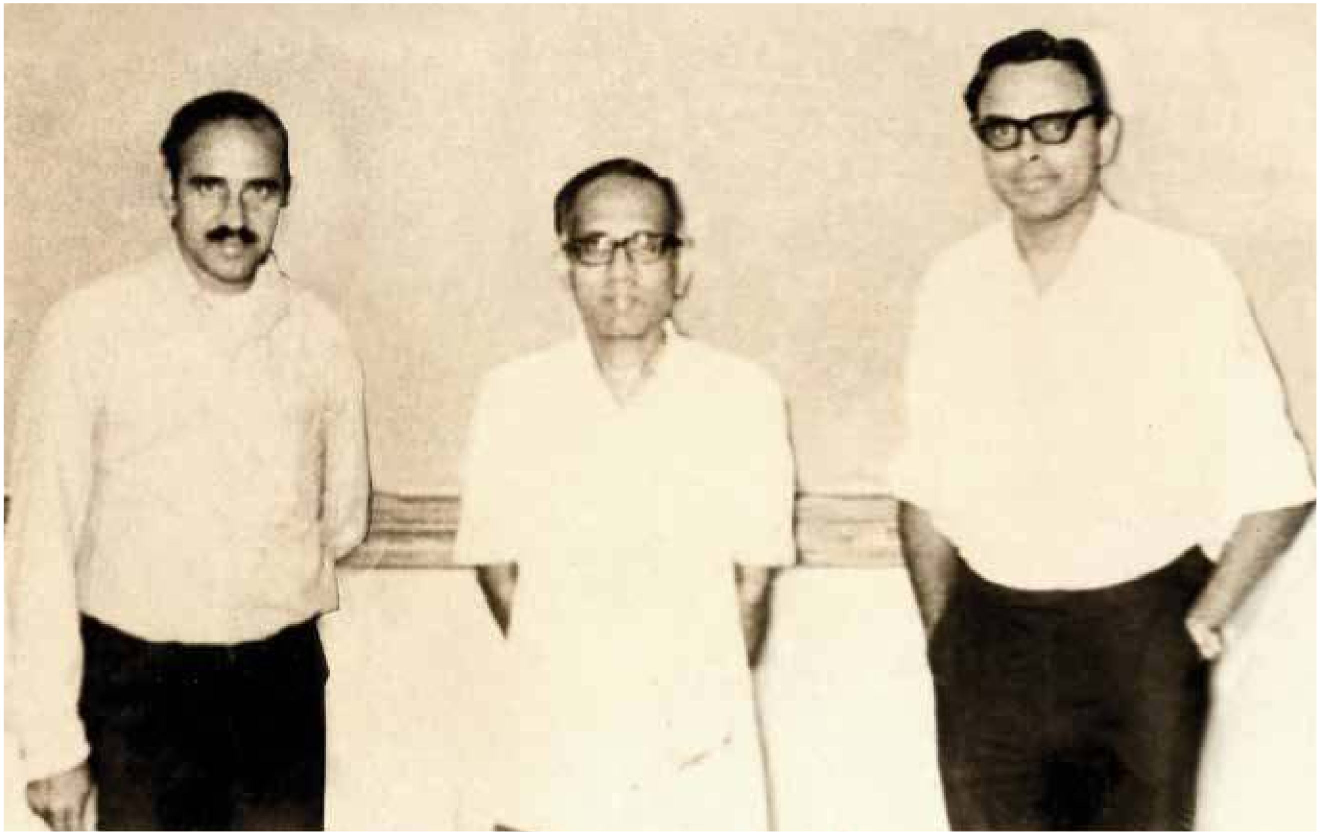
MOLECULAR BIOPHYSICS UNIT, INVOLVEMENT WITH G.N. RAMACHANDRAN AND HIS LEGACY*

G.N. Ramachandran, Genesis

The Molecular Biophysics Unit (MBU) of the Indian Institute of Science was founded in 1971 by G.N. Ramachandran (GNR). GNR was by far the most distinguished scientist to have worked in independent India. A member of a family which originated in Tamil Nadu, he spent his early years in Ernakulam, Kerala, where his father taught in the Maharaja's College. He took his B.Sc. (Hons.) degree from St. Joseph's College, Trichy and D.Sc. under the supervision of C.V. Raman from the Physics Department of the Institute, in 1947. He earned his second doctorate from the University of Cambridge in 1949. He returned to India as a faculty member in the Physics Department of the Institute. At the invitation of the then Vice-Chancellor, A. Lakshmanaswamy Mudaliar, he moved to Madras University in 1952 as Professor and Founder-Head of the Department of Physics (from which the present Department of Crystallography and Biophysics originated). Mudaliar provided all the necessary administrative and financial support to GNR and the latter's mandate was to establish a world-class research centre in Chennai. That was precisely what GNR proceeded to do. A discussion with J.D. Bernal, who was visiting Chennai, was substantially responsible for GNR to enter the field involving the study on biological molecules. He rose to become a global leader in Computational

* Part of the material in this chapter is taken from an article in Current Science (*Curr. Sci.* **115**, 1980-1984, 2018). The portions quoted from the article are given within inverted commas

Members of MBU with Dorothy Hodgkin in 1973.
Sitting (L to R): V.S. Ananthanarayanan, C. Ramakrishnan, V.S.R. Rao, G.N. Ramachandran, Dorothy Hodgkin, K. Venkatesan, V. Sasisekharan and Vijayan. P. Balaram is second from right in the last row. Manju Bansal, then a student, is behind K. Venkatesan, Ashok Kolaskar, then a student, is at the extreme right in the last row.



K.R.K. Easwaran, V. Sasisekharan and Vijayan in the mid 1980s.

Biophysics and Theoretical Crystallography. He was a pioneer in investigations on biomolecular conformation.

Crystal structures of several important biomolecules were also determined by the Chennai group. However, GNR's laurels in crystallography rest on his contributions to the conceptual foundations of the subject.

The first major contribution of GNR and his colleagues in the Chennai group was the determination of the three dimensional structure of collagen in the mid-1950s. Collagen is the one which defied structure solution among the three types of fibrous proteins, despite efforts of veterans like Linus Pauling and Francis Crick. Collagen, which occurs in bone, skin and connective tissues, is the most abundant protein in the animal kingdom. The enunciation of the triple helical coiled-coil structure of collagen by GNR and his colleagues was a landmark in the history of structural biology. Some controversies which eventually turned out to be irrelevant erupted soon after the publication of the coiled-coil structure. Engagement with these controversies led GNR and his colleagues to propose the celebrated Ramachandran map in 1963. This map still remains the simplest descriptor and tool for validation of protein structures. GNR spent only less than two decades in Chennai. During this short span, his group made several outstanding contributions to the structure and conformation of different types of biopolymers.

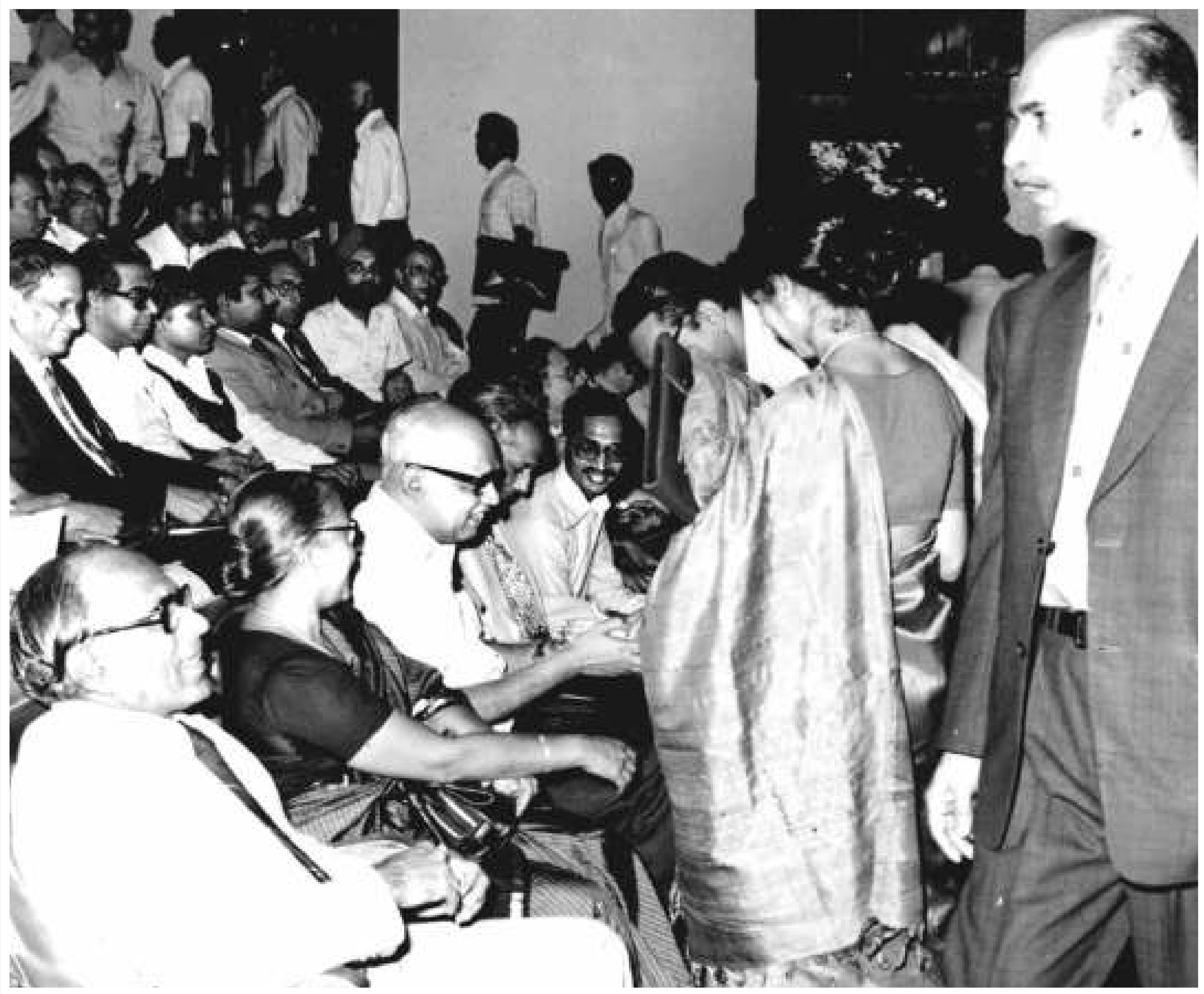
In the second half of the 1960s, the ambience at the Madras University changed drastically after the retirement of Mudaliar and on account of external factors. GNR was uncomfortable in the new ambience. He left Chennai in 1970 and spent a sabbatical year at the University of Chicago, USA. On his return to India, he joined the Institute in 1971. Originally, his avowed intention was to have a small research group christened as the 'Molecular Biophysics Unit'. However, it rapidly developed into a full-fledged department. All the same, the name 'Molecular Biophysics Unit' was retained.

V.S. Ananthanarayanan and K.R.K. Easwaran who had just finished their post-doctoral stints abroad were the earliest colleagues of GNR at MBU. They became Assistant Professors in 1972. In the same year, V. Sasisekharan, V.S.R. Rao and C. Ramakrishnan, his former colleagues in Chennai, joined MBU, the first two as Professors and the third as Assistant Professor. I moved to MBU for all practical purposes in 1973, although formally I was attached to the Physics Department in an *ad hoc* position. I was made an Assistant Professor in MBU in 1974. In the meantime, P. Balaram joined MBU as a lecturer in late 1973. The last appointment during the early phase was that of R. Chandrasekharan in 1974 as an Assistant Professor. K. Venkatesan of the Organic Chemistry department was associated with MBU for a few years as adjunct faculty.

Establishing the X-ray lab and early preoccupations

The first thing I did after being formally appointed as a faculty member at MBU was to apply for a research grant from the University Grants Commission (UGC). It was D. Shankar Narayanan, then the Additional Secretary at UGC, who processed the grant application. The proposal was funded in 1975 with a princely sum of Rs. 1.9 lakhs for 3 years! That was the first competitive grant I received. Since then I have handled dozens of projects worth several tens of crores of Rupees. Although Rs. 1.9 lakhs might sound small by present day standards, it was a large sum in 1975. In the grant, Rs. 1.6 lakhs were for capital equipment. With that amount, I could purchase an Indian made X-ray generator called Radon House, a locally fabricated Weissenberg camera, a precession camera and a polarizing microscope, in addition to small pieces of laboratory equipment. Importing the precession camera was a Herculean task involving obtaining several clearances, a far cry from the present day situation. Radon House was a primitive X-ray generator which I normally operated at 300 Watts! Through Plan grant, I could obtain another Radon House generator. In addition, M.A. Viswamitra donated to me a locally made Weissenberg camera.

The first organizational effort I undertook after joining MBU was as the Secretary of the Organizing Committee of the National Seminar on Crystallography held in Bengaluru in 1974. GNR was the Chairman of the committee. Since then, I have been involved in organizing a large number of national and international meetings but the first one I organized is still fresh in memory. The 1974 meeting was also memorable for the presence of Alex Rich in it as a guest. GNR and Alex Rich (along with Francis Crick) were on opposite sides of the controversy on the structure of collagen. The 1974 meeting was in a sense an occasion for the reconciliation between the two. As indicated earlier, MBU had grown within a span of less than three years from its inception into a full fledged department with nine faculty members, their students and associates. The team was well balanced with different strands of molecular biophysics, currently referred to as structural biology, represented in it. The age distribution among faculty members was also optimal. Scientific results began to flow from the team fairly early on. The rapid expansion, however, inevitably created some turbulence, much of which had to do with laboratory and office space. MBU started in four rooms in the Lecture Hall Complex, with no provision for experimental work. As a result of a great deal of campaigning, two more locations were acquired, by the end of 1970s. The X-ray laboratory and the workshop came to be located in a hall kindly lent by the Department of Civil Engineering. The wet laboratory and the offices of experimentalists were in the old Chemical Engineering building which was vacated by the members of that department, when a new building was constructed for them. This was obviously not a convenient arrangement. As for myself, I had to shuttle among three locations every day, the departmental office in the Lecture Hall complex, the X-ray laboratory in the Civil



Kalyani and Vijayan felicitating G.N. Ramachandran on his 60th birthday. Gopinath Kartha is in the right foreground.

Part of the X-ray group with Nori Sakabe in the mid-1980s.
(L to R) : C.G. Suresh, Dinakar Salunke, Sakabe, V. Dhanaraj, B. Veerepandian, Vijayan, Shekhar Mande, R.V. Thampan.

Engineering Department and the wet laboratory in the old Chemical Engineering building. MBU had no lecture hall. Most of the time, lectures were conducted in the hall kindly made available to us by the Microbiology and Cell Biology Laboratory. We used other lecture halls in different departments when large participation was expected. In spite of all those constraints, research at MBU progressed satisfactorily.

Attrition and turbulence

The period 1977-79 was marked by attrition. R. Chandrasekharan and V.S. Ananthanarayanan left MBU for USA and Canada in 1977 and 1979, respectively. Most importantly, GNR left MBU in 1978. He was a Fogarty Fellow at the National Institute of Health, USA, during 1977-78. That apparently provided him with an opportunity to contemplate his future endeavours. On his return from USA, he called all of us and indicated his desire to leave MBU. Later, I have had discussions with GNR as to why he took such a drastic decision. According to him, he felt that he had nothing more to offer to structural biology. Therefore, he was keen to explore other pastures in subsequent years. The best way to do so was to make a clean break. Much of his later work was concerned with subjects like mathematical philosophy and scientific logic.

As I mentioned in the *Current Science* article, "We were devastated by the departure of GNR. The situation was akin to Hamlet without the Prince of Denmark. An event of this consequence naturally led to a spate of rumours and speculations. Some felt that GNR left as he was not satisfied with our performance, while some others felt that we had not been sufficiently solicitous about him. In the middle of this cacophony, we as a young group felt defenceless. It was important to establish that the relation between GNR and the rest of us was cordial. An opportunity for doing so arose when Dorothy Hodgkin, the celebrated British Nobel laureate, visited IISc in 1979. On account of my close association with Hodgkin, I was largely responsible for organizing her programme. One of the major events we organized was a symposium on the structure and conformation of DNA. That was the hot topic then in view of the major contributions Sasisekharan made in the area. We requested Dorothy to inaugurate the symposium. GNR greatly admired Dorothy. She, considerably senior to GNR, had always been a calming influence on him. GNR readily accepted our invitation to chair the inaugural function. We therefore had two stalwarts gracing the function. GNR was all praise for us in his presidential address and also extended his best wishes to us. That effectively put an end to the unpleasant discussions on the departure of GNR from MBU."

Expansion and consolidation

To quote from the same article, "After the departure of three colleagues, including GNR, we were six faculty members in MBU. Among them, Sasisekharan and Rao were in their 40s. Ramakrishnan, Easwaran and I were in the latter half of 30s, while Balaram was just about 30. We were by and large an undecorated team and had hardly any influence to speak of. Yet, we received considerable appreciation and support on the basis of performance. The team was well balanced, not only in age, but also in subjects of specialization. Half of the team consisted of primarily computational biologists, all with the Madras background, while the remaining three were primarily experimentalists. Among these three, one was a crystallographer, another could be described as an expert in physico-chemical studies and the third was a bio-organic chemist. These six faculty members formed the core group which started the journey of MBU as a coherent department. In the meantime, part of the new MBU building got ready. In addition to space for general facilities, the then new building had six separate laboratories for the six existing faculty members. Five of us moved into the new building and Balaram chose to remain in the old Chemical Engineering building. The MBU building was subsequently expanded stage by stage to what it is today.

"With the completion of the first part of the new building and the prospect of further expanding it, MBU was set for the next expansion. Five appointments were made during 1981–1984. There was a felt need for a biochemical component in MBU. Thus, one appointee was A. Surolia, who already had established collaborative arrangements with MBU for structural studies on proteins. S.K. Brahmachari, an old student and a new faculty appointee, had by then added biochemistry and molecular biology to his repertoire. The need for strengthening the computational biology component prompted the appointment of Manju Bansal, an old student, and Saraswathi Vishveshwara. Finally, M.R.N. Murthy was recruited with the avowed intention of initiating virus crystallography."

GNR provided the leadership as long as he was in MBU irrespective of who was formally the Chairman. At the time he left, Sasisekharan was the Chairman and he effectively assumed the leadership of MBU. He continued in that position till the end of 1984. His distinguished leadership was substantially responsible for converting MBU from an outfit primarily centered around a pre-eminent leader, to a normal department. I and Easwaran closely worked with him.

Foundation of state of the art X-ray lab

Sasisekharan had an interest in X-ray diffraction. That overlapped with my interest as an X-ray crystallographer. In terms of X-ray studies, the immediate task was to develop a laboratory in the huge space provided for it in the MBU building. In an early research grant obtained by Sasisekharan, there was provision for importing a good, sealed tube X-ray generator. By then, difficulties in importing equipment had eased, primarily on account of the strength India gained after the Green Revolution. We christened that X-ray generator 'High Hope 1' (HH1). A similar generator I obtained in a grant, was called HH2. A reasonable number

K. Suguna greeting Kalyani and Vijayan on his 60th birthday.

M.R.N. Murthy, Guy Dodson, Vijayan and B. Gopal in 2009.

of X-ray diffraction cameras could also be obtained. A dramatic turn of events took place when the DST decided to support us in a big way in 1983 under their Thrust Area Programme. The big grant was provided for a project involving fibre diffraction studies of DNA and macromolecular crystallographic studies on proteins, based on a proposal submitted by Sasisekaran, myself, Surolia and Samir Brahmachari. That turned out to be a turning point in the development of macromolecular diffraction studies in India, which deserves a separate chapter. I was perceived as the central figure in carrying out the project and for taking the responsibility for the long term development of the area. However, I could not have managed it without the patronage and whole hearted support of Sasisekharan who was by then an established scientist.

Our effort was to infrastructurally equip the X-ray lab for its continuous long term usage. To start with, the whole lab was air conditioned using six units. It was decided that crystallization experiments would be conducted in appropriately devised enclosures in the X-ray lab itself, to avoid air conditioning additional space for the purpose. The Institute would not provide air conditioners. The granting agency was also not in favour of providing air conditioners. Therefore, with the full concurrence and co-operation of all concerned, we had to formally rename air conditioner as some special equipment in formal documents! We also decided to provide uninterrupted power supply (UPS) devices for all instruments including the air conditioners. That was a time when UPSs were just coming into vogue and, therefore, we had great difficulty in procuring high power capacity instruments of that type which did not produce too much of noise and heat. All the UPSs were then backed up with a 110 kVA diesel generator. Thus, it was effectively ensured that power never failed in the X-ray lab! It took immense efforts on our part to organize the lab on the lines outlined above. However, it was a worthwhile effort as it is from this laboratory that much of macromolecular crystallography in India radiated. It is also remarkable that the lab we set up in the early 1980s is still in use without substantial modifications. Colleagues who worked with me in building up the X-ray lab in addition to Sasisekharan, were M.R.N. Murthy, K. Suguna and later B. Gopal. More recently Aravind Penmatsa joined MBU as a faculty member, with active involvement in running the X-ray lab. Technical support, initially of C. Govindaswamy and later James Paul, was very important. The other technical personnel who helped were Dhruva and Babu. In fact, we all worked as a team.

Chairmanship and beyond

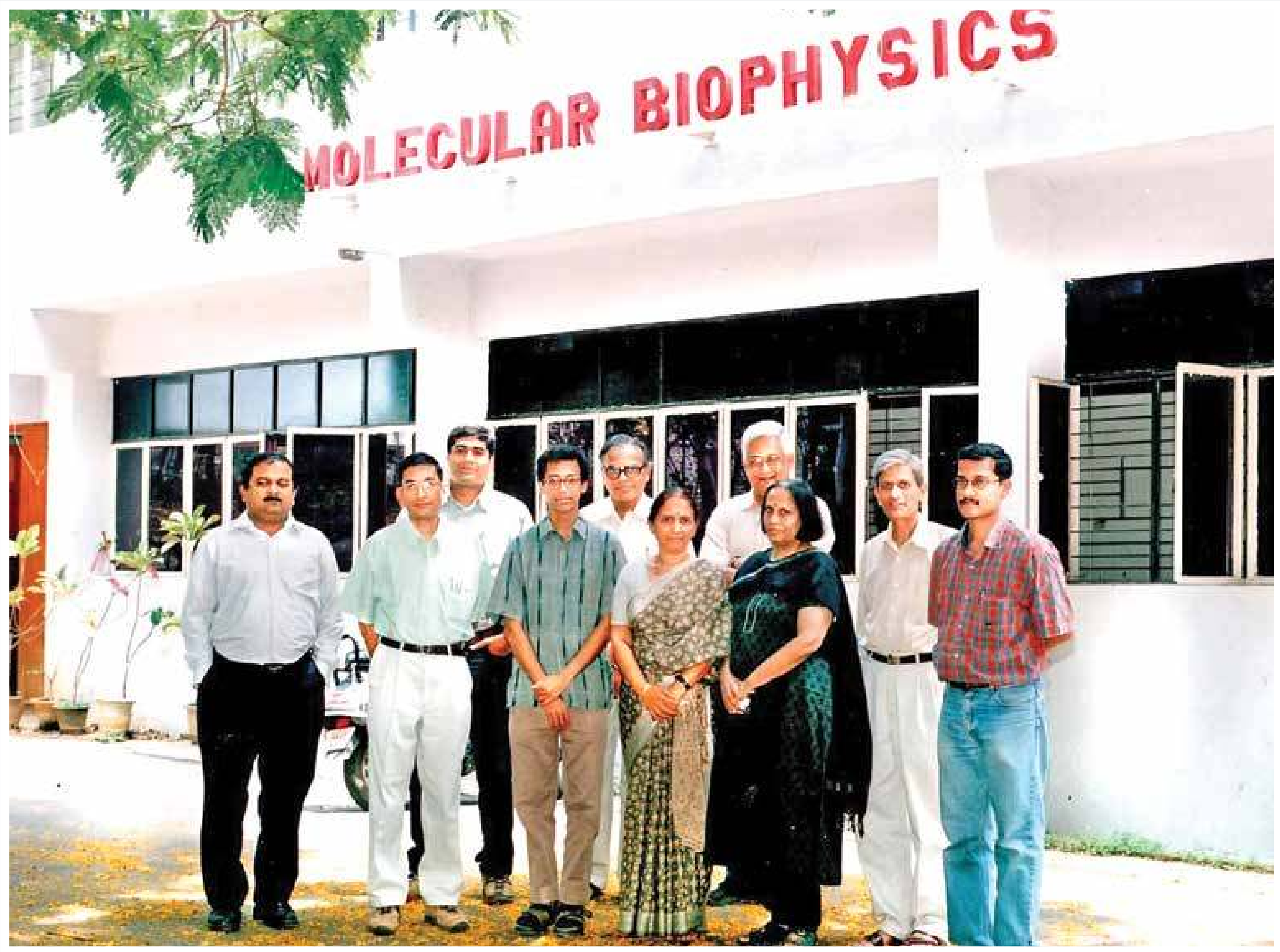
Sasisekharan relinquished the Chairmanship of MBU in December, 1984 after organizing a widely attended International conference. During a large period of his Chairmanship, I worked closely with him. It was a unanimous view of the faculty that I should succeed him as the Chairman, a view, endorsed by the Director and the concerned Divisional Chairman. By that time, I had become a full Professor. I assumed office in January, 1985. Sasisekharan went on to become the Dean of the Science Faculty and then the Chairman of the newly formed Division of Biological Sciences.

My first job after assuming the Chairmanship was to defend our proposal at the UGC for infrastructural support under the COSIST programme. On a wintery day, heads of many important university departments across the country had assembled at UGC to present the respective proposals. Most of them were senior scientists and suitably attired. I was comparatively young at 43 years of age. The colleague who accompanied me to the event was P. Balaram who was still younger. We probably were an odd lot among the senior professors assembled there.

The forenoon session was devoted to preliminary discussions with officers from UGC and DST. Most of them knew us. However, the newly appointed Head of the COSIST operation was a senior professor from an old university and was substantially innocent of the scientific landscape of India, particularly in the biological sciences. He quizzed us extensively in a somewhat condescending manner, which was annoying. Many of the other officers present there who knew us, were also uncomfortable. Balaram and I answered his queries as well as we could. However, that experience put us on the alert. We met the main committee chaired by the well-known scientist and administrator P.N. Srivastava, in the afternoon. We were very guarded and I started the presentation by telling that the Committee might wish to listen to our justification of the requirements we had projected. P.N. Srivastava smiled and said "we know you and your work. All that we want to hear is what you want from us". A pleasant anticlimax.

An early event which took place soon after I took over the Chairmanship was concerned with the Bhopal tragedy of 1984. V. Ramalingaswamy, the then Director General of the Indian Council of Medical Research (ICMR) and S. Sriramachari, its Additional Director General, visited the Institute for discussions on the scientific aspect of the Bhopal tragedy and associated remedial measures. Although I was the youngest and the junior most among the Chairmen of biology departments, the Director asked me to organize the discussion. We then had a brain storming session with selected members of the biology faculty, coordinated by the visitors.

That was the first time I had the occasion to interact closely with Ramalingaswamy and Sriramachari. I have had several such occasions later. Ramalingaswamy was a giant among medical scientists of India and the world. His accomplishments are too well known to be touched upon here. On all occasions, particularly when we worked together in the Scientific Advisory Committee of the National Institute of Immunology (NII), he had treated me with great kindness. What struck me most was his graciousness. I am yet to find a person more graceful than Ramalingaswamy. I also have had the good fortune to interact with Sriramachari on several occasions. His monumental service to the country, particularly his Herculean



Some members of the MBU faculty in front of the Molecular Biophysics building in 2004.
(L to R) : N. Srinivasan, P. Balaram, Siddhartha Sarma, Raghavan Varadarajan, Vijayan, Saraswathi Vishveshwara, Dipankar Chatterji, Manju Bansal, A. Surolia, B. Gopal.

Vijayan in his MBU office which he used for four decades.

efforts along with S. Varadarajan at Bhopal, had been awe inspiring. The last time he contacted me was a couple of weeks before his death. I was then the President of INSA and had just published an article on Indian Science, in *Frontline*. He graciously complimented me on that article. He also mentioned about plans for observing the 25th anniversary of the Bhopal tragedy.

My Chairmanship of MBU happened to overlap with the period when many of us got recognized in Indian Science. Sasisekharan and V.S.R. Rao, the senior most and the oldest among us, had by then received national and to an extent, international recognition. Recognition for some of the rest of us, came in quick succession, during that period. Four faculty members from MBU received Bhatnagar prizes successively in 1984, 1985, 1986 and 1987, which is perhaps somewhat unusual for any department. Two more colleagues who joined MBU before 1985, received Bhatnagar prizes, one in 1990 and another in 1993. Many of us got elected to national science academies also during this period.

When I assumed office in January 1985, I was primarily dealing with a team of comparatively young and brilliant faculty members in MBU. Most were highly motivated and intense. They also had strong views. There were differences of opinion and intense discussions. The young faculty expressed their strong views outside MBU as well. I recall a senior colleague asking me in half jest how I simultaneously managed Balaram, Surolia and Samir! In fact, I had no difficulty although arguments were sometimes inconvenient. It is also worthwhile recalling what profiles the three later had in Indian science. Arguments were often acrimonious but it did not affect personal relationships and coherence of the department. All remained life-long friends, helping one another as and when required.

As Chairman, I spared no efforts to hold all the colleagues together, which sometimes meant dealing with youngsters sternly. I remember Samir, who was then DG, CSIR, mentioning to me much later that I had scolded him as much as I would have scolded Devi (my daughter)! I then jokingly responded by saying “the only difference was that I had still some control over you!” In spite of arguments on procedures and policy matters, we were a reasonably coherent team.

The administration of MBU was collegiate as we discussed all issues among ourselves. There used to be hardly any serious disagreement on the distribution of common funds obtained from the Institute and as part of the COSIST programme, the Centre of Advanced Studies (UGC) etc. There were several occasions when the faculty members stated their requirements and left it to the Chairman to take the final decision. My hands were strong in doing so as I rarely dipped into the common funds for my research, from the time I became the Chairman till now, except on a single occasion when the X-ray crystallographers in the department were offered funds in a platter. I used to procure resources for running the X-ray lab and for my research from different granting agencies, particularly DST.

The exception referred to above touched me deeply. By the mid-1980s, we had set up a state of the art X-ray lab, mainly using funds granted by DST. In the second half of the 1980s, area detectors rapidly became the instruments of choice for X-ray intensity data collection. I was hesitant to go back to DST for additional funds. However, my colleagues in MBU strongly felt that we deserved an area detector, especially in view of our role as a nucleus for the development of macromolecular crystallography in India. When this discussion was going on, a new phase of the Centre for Advanced Studies programme became operative. The total equipment grant under the programme was Rs. 30 lakhs (a huge sum at that time). The MBU faculty collectively decided that the whole equipment grant should be used to purchase the area detector. I was embarrassed. As the Chairman of the Department, I felt that I could not use the grants for an instrument of which I would be one of the main users. At the end of the protracted discussion, I recall Balaram mentioning "we are not giving any money to you. We are giving it to Murthy (my younger colleague in the X-ray lab)". That clinched the issue.

An area detector then costed Rs. 45 lakhs. We then approached the DST for the additional Rs. 15 lakhs. They were happy not only to provide the additional amount but also to undertake the full maintenance of the facility, provided we agreed to treat it as a national facility. That was anyway our intention and I readily agreed to this condition. The only caveat I made was that treating our facility as national facility should not come in the way of other centres receiving funds for area detectors.

We waited several years for the appointees in the early 1980s to settle down, before making further regular faculty appointments. The appointments during my Chairmanship were those of S.K. Sikdar and Raghavan Varadarajan in the early 1990s. That was a time when electrophysiology was becoming increasingly molecular. Erwin Neher had just been awarded the Nobel Prize in the subject. After a great deal of discussion, we thought we should add expertise in this area to our repertoire. That was how Sujit Sikdar came to be appointed. Raghavan Varadarajan is a biophysical chemist and molecular biologist, who neatly fitted into the research theme of MBU. Although I moved to the central office soon afterwards, I continued to be involved in the appointments in MBU, as the Chairman of the Biology Division, a constituent department of the Division. V.S.R. Rao and Sasisekharan formally retired in 1991 and 1993, respectively. N. Srinivasan, a former student, was appointed as a faculty member to partly fill the void created by the departure of the two veterans. In the meantime, Samir Brahmachari, by then a Professor, left to take up the Directorship of a CSIR laboratory in Delhi. Dipankar Chatterji, already a well-established scientist, was appointed as a Professor in his place. Thus, by the turn of the century, MBU was made up of about a dozen faculty members and their students and associates. Most of the faculty members were by then well established, and we had ceased to be the young, green horns that the original members of the group were in the late 1970s.

After I relinquished the Chairmanship towards the end of March 1992, K.R.K. Easwaran was the Chairman of MBU for about three years. Easwaran was succeeded by P. Balaram. By then, I had become the Chairman of the Biology Division. Balaram succeeded me as the Divisional Chairman when I became the Associate Director of the Institute in early 2000. Balaram, of course, went on to become the Director of the Institute. Happily, all the changes in the Chairmanship of MBU were smooth and were based on the consensus among the faculty. My involvement with the administration of MBU reduced substantially after I became the Associate Director, although MBU continued to be my platform for scientific research. Therefore, it is perhaps not appropriate for me to comment on the administration of MBU beyond 2000.

Often, the unsung heroes of a science department are the supporting staff. I have had perfect rapport with the office staff of MBU during my decades of association with it going well past formal retirement. Those with whom I worked include R. Venkataraman, S.N. Subbaramu, Bullock, K. Sundareswara, T.K. Raveendran, U.S. Balachandra, Radha Ramachandran, K. Indira and S. Shivashankar. Chayapathy who was earlier in the Registrar's office also joined MBU, towards the end of his career. My longest association was with Shivashankar who joined MBU just before I became the Chairman. I have already referred to the supporting staff in the X-ray lab. Among other technical staff, the one closest to me was M. Jagannatha Rao. I always had a personal assistant from 1979, starting with Nagapraba. Another person who worked in that capacity, for more than a decade was K.B. Shobana who prematurely died in 2003. C. Pankaja who initially joined me in 1999 when Shobana was on maternity leave, has since been my Secretary. My family and I cherish the two decades long association we have had with her. The association became stronger after I became physically disabled (see later). She effectively grew to be the manager of my lab and to an extent, the X-ray facility, respected by all students and post-docs.

Peer recognition

"Although MBU started its uninterrupted journey as a coherent department with a small group of relative green horns at the core, eventually members of MBU turned out to be a highly decorated group. Among the 16 faculty members who worked at MBU during 1980–2000, 10 obtained the Bhatnagar Prize. Almost an equal number were elected to all the three science academies of India. From among them, half a dozen are fellows of The World Academy of Sciences. The President of India awarded Padmashri and Padma Bhushan to one and Padmashri to two others. Those who occupied important positions at the Institute have already been referred to. One of the faculty members became the President of the Indian National Science Academy, another the President of the Indian Academy of Sciences and yet another the Director General of the Council of Scientific and Industrial Research. Many in MBU occupied important positions in international organizations as well. Several former students of MBU have also been recognized with awards, fellowships and important positions". For instance, the present CSIR DG, Shekhar Mande, a former student of mine, is the second former student/ faculty of MBU to hold that position.

General remarks

"From a somewhat disorganized, and to an extent turbulent, beginning in the 1970s, how did MBU emerge as a well-recognized department by the end of the 1980s and also remain so subsequently? There is no simple answer to this question. While what is given in the foregoing is substantially a factual narrative, the attempt to answer the above question is primarily based on my personal observations and opinions.

"The fact that MBU was founded by the great scientist GNR by itself gave it a head start. The rapid expansion in the first couple of years led to considerable disorder, but did not affect the high level of scientific operations that the involvement of GNR engendered. His choice of faculty members was well balanced. All computational biophysicists among them were his former students/colleagues from the University of Madras, while the experimentalists came from different institutions with varied backgrounds. Thus GNR assembled a team of young faculty members with complementary expertise among them, to pursue a common theme in research. Such a potent group could have been brought together within a couple of years, only by GNR. It is another matter that the whole group did not remain intact for long. As indicated earlier, only six of us remained at MBU by the end of the 70s. By then, we had inculcated a tradition involving synergy between that bequeathed by GNR and those brought by some of us from other internationally famous research schools.

"In further faculty appointments at MBU, care was taken to see that proper balance within the organization was maintained. During the period under consideration, the research activities in MBU could be roughly categorized into three streams: (a) computational biology, (b) X-ray crystallography and (c) physico-chemical, biochemical and spectroscopic studies. Although this division was by no means watertight, an effort was made to ensure a reasonable balance among the three streams. Within each stream, the attempt was to ensure a spread of age groups in order to avoid unhealthy competition among the faculty. To an extent, the older members functioned as mentors of junior faculty. The proper balance among different disciplines and age groups facilitated extensive collaboration among the members of MBU faculty.

"Coherence within a department needs to be preserved and promoted by deliberate action; it does not often happen automatically. In any group, particularly in those made up of brilliant self-driven persons, disagreements do occur. The responsibility of the leadership is to try to resolve them expeditiously and ensure that they do not degenerate into permanent squabbles. In this respect, MBU has been reasonably successful. It was perhaps commonality of the research theme of the different groups, the complementary expertise of different faculty members which engendered extensive collaboration among them and the camaraderie among the members of the unit, which enabled MBU to orchestrate as a single entity.

"What I have outlined above is a brief history of MBU till the turn of the century and what I perceive as the factors which helped it to perform well. The period beyond 2000 is too close to the present time to be assessed objectively. Furthermore, although MBU continued to be the platform for my research and engagement with Indian and international science, I naturally dissociated myself from the administration of MBU after my formal retirement in 2004 (incidentally, as Raja Ramanna used to say, I have since then retired from different positions several times!). In any case, hopefully, the story of MBU holds some lessons for the scientific community".

Involvement with GNR and his legacy

I had known GNR from the first time I met him in 1963. However, I interacted closely with him only for a little over three years in the 1970s. All the same, we became close to each other. Even after he left MBU, we were in touch with each other. My relationship was as easy as possible with a complex person like GNR. He often took me into confidence with his problems and concerns. I, of course, admired GNR. However, I was my own person and did not directly owe anything to him. Perhaps, the closeness, but absence of intimacy, engendered good relationship between GNR and myself.

GNR was a complex person. He was a great scientist and extraordinarily kind human being. He was a connoisseur of music. On the other hand, he was a highly strung person who could lose his cool, even control, easily. The inadequacy of the recognition he received greatly bothered him. He had a proclivity to become unhappy. He himself was aware of it. In 1977, on his way to USA, he stayed in England for a couple of days. That was the time when he received the Fellowship of the Royal Society. I was in Oxford at that time and was involved in organising his programme in England. As both of us were far away from the place of work, our conversation was relaxed and informal. While we were in a taxi in London, I explained to him the difficulty, primarily health issues of her husband, which Dorothy was going through. But she always remained cheerful and I told GNR that when she came to the lab everyday, she always looked for something to be happy about. GNR responded "you know Vijayan, I am just the reverse. I always look for something to be unhappy about"!. Although said in jest, this was substantially true. Dorothy had infinite capacity to be happy about small things. She published two papers in 1988, one a celebrated paper on the detailed structure of insulin in *Philosophical Transactions of the Royal Society* and the other on the structure analysis of a small molecule in *Acta Crystallographica*, Section C, which was then meant for simply recording structural results. Dorothy would have been happy about both the papers! GNR, on the other hand, always looked for important results which naturally happened only infrequently. That often made him unhappy.

It is true that he did not receive the recognition he deserved even in India, except in scientific circles. He did not receive even a Padmashri, although he was truly a Bharat Ratna (these are highest civilian honours of India). I used to address every year the introductory function or the valedictory function of the KVPY programme, when I was the Associate Director. On each occasion, I used to request the students to list the names of Indian scientists they have heard of. I used to do this on other occasions also when I addressed students elsewhere. Everybody had heard of C.V. Raman and Abdul Kalam. Most of the other names students mentioned were those of science administrators. Very rarely, they named GNR. That was an index of the hierarchical nature of our scientific enterprise. GNR was never a Director, let alone a Director General!

The formal international recognition he received was less than that received by many other Indian scientists. He was elected to the Fellowship of the Royal Society rather late in life. Some of us, including my friends like Guy and Eleanor Dodson, Tom Blundell and Ted Baker, were acutely aware of this situation. By the 1990s, we were all active in the crystallography community and the International Union of Crystallography (IUCr). I then took the initiative for nominating GNR for the Ewald Prize in 1999, when Ted Baker was the President of IUCr and R. Chidambaram its Vice-President. GNR was awarded the prize which made him and his associates happy.

Ewald Prize, in a sense, was a consolation prize. He richly deserved a Nobel Prize. Perhaps he was ahead of his time. Many of us were unhappy that he was not awarded the Prize. I mentioned this when introducing Hartmut Mitchel, a Nobel laureate, who gave the Ramachandran lecture in the 2004 meeting at the Indian Biophysics Society. In response, Mitchell said in his address that many Nobel Laureates have been forgotten. However, GNR remained a vibrant presence in international science.

Apart from the personal closeness I had with GNR, I had a special kind of association with him in scientific endeavours. The one thing that GNR wanted to do, but could not, was the initiation and development of biological macromolecular crystallography in India. The time was not ripe for doing so, when GNR was active. Eventually, it was substantially left to me to initiate and nurture the area in the country. Therefore, many perceive me as a successor of GNR. Mention has already been made of the award of the Ewald Prize to GNR in 1999. Ewald Prize is the highest honour IUCr can bestow on a scientist. Conventionally, Crystallography Congresses, held every three years, start with the Ewald Lecture by the awardee. GNR was too unwell to attend the 1999 Congress at Glasgow. The organizers then asked me to stand in for GNR and give the Ewald lecture on his work. I did that with great pleasure. That strengthened the perception of my being a successor of GNR. When GNR died in 2001, I was invited to write the obituary note in *Nature*. I wrote the Biographical Memoirs of him for the Indian National Science Academy. The Royal Society of London invited me to do the same for them. It was obligatory to have a Fellow of the Society also as co-author. My co-author was my friend (late) Louise Johnson. Since then, I have given innumerable lectures on GNR and his legacy. They included the lecture on the legacy of GNR in the 2013 International conference in Bengaluru to commemorate 50 years of the Ramachandran plot.

The awards I received also emphasize my professional relationship with him. When INSA instituted a G.N. Ramachandran Commemoration medal, the first recipient was N.N. Dasgupta, a contemporary of GNR and doyen of Biophysics in Kolkata. I was the second recipient in 1994. I was the first recipient of the medal, when the CSIR instituted the G.N. Ramachandran Gold Medal for Excellence, in 2004. More recently, when the Sastra University instituted the G.N. Ramachandran medal, again, I was the first recipient. I was also involved in efforts to celebrate the GNR legacy. At the turn of the century, through the efforts of Manju Sharma, the then Secretary of DBT, an endowment was created for a G.N. Ramachandran Chair at IISc. I had the privilege of associating myself with these efforts, on behalf of the Institute, and receiving the cheque from M.M. Joshi, at a function in New Delhi. We made sure that the first G.N. Ramachandran Professor was Harold Scheraga, a long term friend and competitor of GNR. Many distinguished scientists have since occupied the Chair. Girijesh Govil and I took the initiative for instituting a G.N. Ramachandran lecture at every Biophysics Congress. Ramesh Mashelkar, who was the then President of INSA and DG of CSIR, acted on our request, found the necessary funds for the Endowment and formally recommended the institution of the named lecture, on behalf of INSA.

It is certainly an honour to be perceived as a successor of GNR. However, I am conscious that I have not even approached the heights that GNR scaled. All the same, there is an element of satisfaction that I could contribute to initiating and developing an area which was close to GNR's heart. I am sure that my younger colleagues in the macromolecular crystallography/structural biology community would again bring as much glory to India as GNR did.

8

INTERACTIONS INVOLVING SMALL BIOMOLECULES, CHEMICAL EVOLUTION LEADING TO ORIGIN OF LIFE, ISRO*

When I returned to India from Oxford in 1971, I would have liked nothing better than initiating macromolecular crystallography in the country. However, the time was not ripe for doing so. Funds available for research were inadequate. Furthermore, appreciation of approaches involving three dimensional structures was low in the biological chemistry community. That made collaboration with biochemists for macromolecular crystallographic studies difficult. While waiting for the situation to improve, it was important to devise interesting programmes which were idea-based, inexpensive and not technology intensive. X-ray crystallography has been the method of choice for determining the structures of small molecules, although it had not then become as routine as it is today. We set about using the technique for exploring inter-molecular interactions and their consequences, by co-crystallizing or making crystalline complexes of the interacting molecules. The rate limiting step in this approach is the actual preparation of the crystalline complexes. It is often difficult to crystallize even a single pure compound. It is all the more difficult to coax two molecules to crystallize together, except in very special circumstances. However, the difficulty is the same, irrespective of whether one is working in an Indian laboratory or a well-endowed laboratory in the West. Once crystals of the complex are obtained, the technological

* Parts of the narrative have been taken from my anniversary address as the President of INSA in the Platinum Jubilee year (*Proc. Ind. Nat. Sci. Acad.* **75**, 98-105, 2009). These parts are given within inverted commas.

requirements for solving their structures using crystallography are not forbidding. The intellectual challenge is in interpreting the structural results obtained. Here again, we have no comparative disadvantage compared to those in the advanced West.

Aspirin - like drugs. Effect of complexation on molecular geometry

The approach involving crystalline complexes was first applied to systems involving non-steroidal anti-inflammatory drugs, often described as aspirin-like drugs. These are among the most widely used drugs. In the early 1970s, there was considerable excitement when it was discovered that aspirin like drugs acted through the inhibition of prostaglandin biosynthesis. As we were pursuing fundamental research, we systematically investigated two classes of such drugs, irrespective of whether they were currently in medicinal use or not. Over the years, we analysed the structures of antipyrine, amidopyrine, metamizole, phenylbutazone, oxyphenbutazone, hyroxymonophenylbutazone, niflumic acid, flufenamic acid and meclofenamic acid, and the complexes of several of them with other appropriate molecules. The programme was wound up somewhat prematurely in the mid-1980s. By that time, my involvement with macromolecular crystallography was becoming intense. Macromolecular crystallography is a jealous mistress and I had to wind up the programme on aspirin-like drugs to concentrate on it, even though the programme was yielding interesting results.

It is not necessary here to go through the major results of the programme. Perhaps the most important result had to do with the effect of interactions on molecular geometry. For example, antipyrine has a heterocyclic 5-membered ring connected to a phenyl ring at a hetero nitrogen of the former. The other hetero nitrogen atom has a methyl group attached to it. A carbonyl group is substituted at a carbon atom in the 5-membered ring. This carbonyl group can form hydrogen bonds with other molecules or coordinate to metal ions (Figure 1). In free antipyrine, the two nitrogen atoms are pyramidal. When the carbonyl group is involved in a hydrogen bond, there is a disturbance in the electronic structure and the two hetero atoms move towards planarity. The planarity is more pronounced when the carbonyl group interacts with a metal ion. In this respect, the nitrogen atom is different from the carbon atom. A carbon atom can be sp^3 hybridized (pyramidal) or sp^2 hybridized (planar). A nitrogen atom, on the other hand, assumes different levels of pyramidality/planarity. When it occurs in the middle of a molecule, as in the case of antipyrine, this variation can have a significant effect on the overall geometry of the molecule. Thus, the work on antipyrine illustrates a case where the geometry of the molecule can be modulated through intermolecular interactions.

Another interesting example also pertains to a pyrazole derivative, viz, phenylbutazone. In phenylbutazone, phenyl rings are substituted at

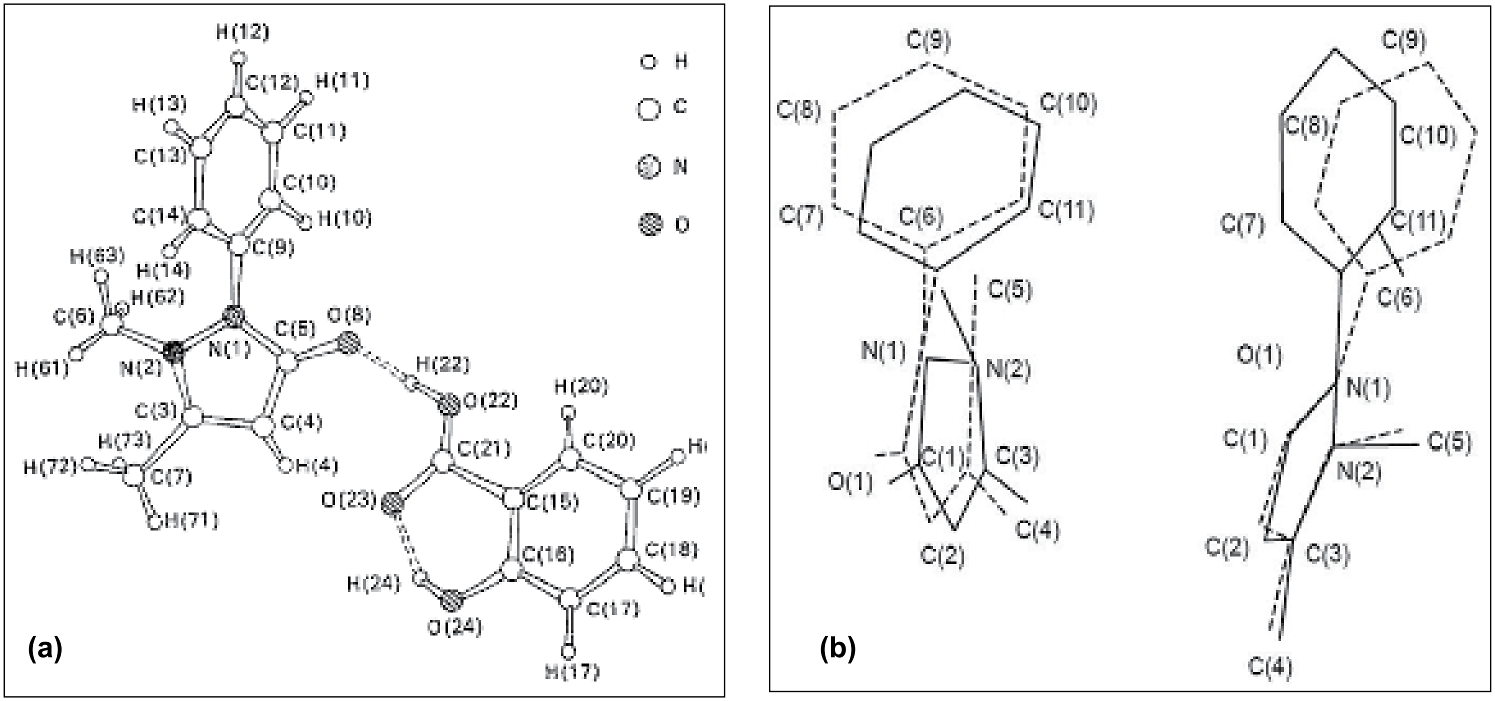


Figure 1. (a) Structure of salipyrine. Adapted from Acta Cryst. **B30***, 557-562, 1974. (b) Two views of the molecule in free antipyrine (solid line) and its metal complexes (dashed line). Adapted from Acta Cryst.* **B29***, 714-720, 1973.*

both the hetero nitrogen atoms of the 5-membered pyrazole ring. At the other end of the ring, a butyl group is attached to a sp^3 hybridized ring carbon atom. This carbon atom is flanked by two carbonyl groups. When the molecule interacts with piperazine, the carbon atom which carries the butyl group is deprotonated and the molecule now carries a negative charge (Figure 2). The hybridization state of the ring carbon atom becomes sp^2 with considerable rearrangement in the three-dimensional and electronic structure of phenylbutazone. Here again, we have a good instance of alteration of molecular and electronic structure caused by an interaction.

It was Tej Pal Singh (T.P. Singh) my first graduate student, who initiated the work on aspirin-like drugs in the laboratory. He went on to become an important leader of structural biology in India and abroad. Tej Pal, his wife Meera and daughter Vineeta became our family friends. Two more graduate students worked on the problem. One was H.M. Krishnamurthy. The other, V. Dhanaraj died prematurely. He and his wife Rajshree were close to us.

A deviation from the theme. Ionophores, related compounds and peptides.

During the same period, I was also involved in

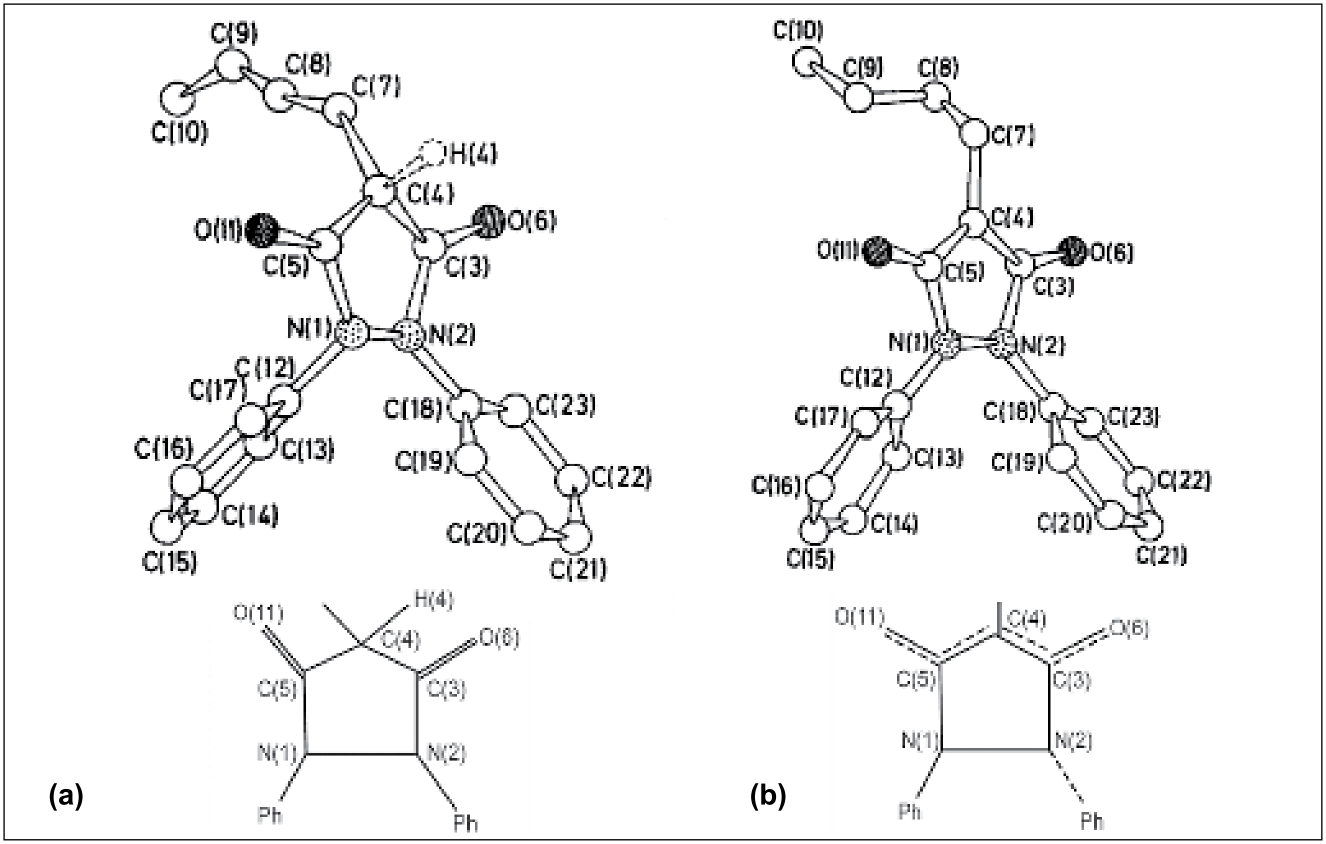


Figure 2. (a) Structure of phenylbutazone in (a) in its crystals and (b) in the crystals of its complex with piperazine. Adapted from J. Chem. Soc. Perkin **II**, *693-699, 1977.*

collaborative efforts with K.R.K. Easwaran and P. Balaram. The work with Easwaran was on carrier ionophores. My students were not involved in these efforts. The structural work was carried out by Easwaran's students under my supervision. The most important result to emanate from this work was the characterization of a novel conformation of valinomycin, which was published in *Nature* in 1980. A substantial part of my work with Balaram was on peptides related to channel-forming ionophores. Part of the work formed a component of the celebrated efforts of Balaram on peptides containing conformationally restrictive amino acids. C.M.K. Nair (who joined the lab under the Faculty Improvement Programme), and A.K. Francis obtained their doctorates working in the collaborative programme with Balaram. C.M.K. Nair (Mohan, as we call him) subsequently had a useful career at Thiruvananthapuram. We have had several interactions with Mohan and his family. Francis settled abroad. The peptides studied included a beta turn forming tetra peptide, the structure of which was determined under my supervision by Samir Brahamachari who was then a student of V.S. Ananthanarayanan.

Molecules of life and their monomeric constituents

Before I deal with our work on crystalline complexes involving amino acids and peptides and their evolutionary implications, it is perhaps appropriate for the benefit of the uninitiated, to outline a few relevant basic facts about biomolecules. For millennia, philosophers, scientists and laymen have asked the question, 'what is life?', Living organisms and the way they live are so diverse that even now there is no universally accepted simple definition of life. Perhaps, we can ask a simpler question: 'which molecules are most characteristic of life?' If we examine ourselves, we would find that the human body is made up of 60 to 80% water. As J.B.S. Haldane is once reported to have remarked, even the Archbishop of Canterbury is 60% water. Then there are proteins, nucleic acids, lipids, carbohydrates and an incredible variety of other molecules and ions. Most of them are essential for normal life processes. Even bacteria contain far too many different types of molecules and are far too complex to enable us to answer the question. We can go to the twilight zone between the living and the non-living, the domain of viruses. There are viruses which infect animals, plants and even bacteria. Viruses when outside their host, behave like inanimate matter. You can even crystallize them and study their structure using crystallography. However, once they are inside the host, they behave like living organisms. The simplest of viruses consist of a nucleic acid molecule and a number of proteins. Many of the simple viruses are in fact a nucleic acid molecule encapsulated in a protein coat. All normal living organisms contain nucleic acids and proteins. We can thus conclude that nucleic acids and proteins are the molecules that are most characteristic of life.

We know even the respective roles of nucleic acids and proteins. Nucleic acids, particularly DNA, are primarily informational molecules. The other type of nucleic acids, viz., RNA, can carry information as well as take part in metabolic processes. Even when they are involved in metabolic processes, their role is primarily in information transfer. All the information required for synthesizing proteins is encoded in DNA. Once the proteins are made, much of the life processes are carried out by proteins. Thus, as the saying goes, if DNA is the blue print of the machinery, the machinery itself is largely made up of proteins.

A living organism contains many molecules other than nucleic acids and proteins, most of them synthesized by enzymes which of course are a type of proteins. These other molecules include carbohydrates, lipids, and very many kinds of small molecules. The bulk of bio-molecules, like nucleic acids, proteins and carbohydrates are biopolymers. The monomers of these biopolymers and the building blocks of all other biomolecules put together amount to only less than a 100 small basic molecules. These may be called the molecular alphabets of life. It is the permutations and combinations of these molecular alphabets that give rise to the entire biosphere. There is a common fundamental way in which these alphabets combine and permute and the resulting biological macromolecules like nucleic acids and proteins function together. This may be described as the molecular logic of life. You may call it, if you like, the molecular grammar of life. This molecular logic or grammar is central to modern biology.

As mentioned earlier, the critical components of the machinery of life are made up of proteins and molecules synthesized by a class of proteins called enzymes. Therefore, exploration of the structure and function of proteins is central to biology. In spite of the enormous structural and functional diversity of proteins, they all have essentially the same kind of composition. All of them are linear, condensation polymers of 20 monomeric units called amino acids. To use an imperfect analogy, just as the English language is made up of the permutations and combinations of 26 alphabets and few punctuation marks, the protein universe is made up of permutations and combinations of 20 amino acids. When two amino acids are linearly joined together, you get a dipeptide. When the number is three, you get a tripeptide. When a few amino acids join together linearly, what results is an oligopeptide. When a large number of amino acids are involved, what results is a polypeptide. All proteins are polypeptides typically consisting of 100s of amino acids. The sequence of amino acids is coded in the DNA. Once polypeptides are formed using a synthetic machinery called ribosome, it generally folds into a characteristic shape through a self assembly process. Thus, the sequence of a protein determines its three-dimensional structure, which in turn, leads to its function. However, our understanding of the complex forces that stabilize protein structures is not good enough to enable us to predict the protein structure from the knowledge of the sequence. The structure has to be determined experimentally, primarily using X-ray crystallography.

Crystalline complexes involving amino acids and peptides

The structure, assembly and function of proteins critically depend upon a large number of non-covalent interactions. It is these weak interactions that are largely responsible for the high versatility and subtility of biological systems. A great deal of information on these interactions has been provided by protein crystallography, NMR and electron microscopic studies. However, these approaches do not generally provide information at atomic resolution. On the other hand, structures of small molecules like amino acids and peptides can be determined by X-ray crystallography at atomic resolution. It was also interesting to see how they interact among themselves and other biomolecules. Taking into account these factors together, the initial motivation for starting the work on crystalline complexes involving amino acids and peptides was to determine at atomic resolution, the geometrical features of the non-covalent interactions important in the structure and function of proteins.

The most difficult step in the work was again the preparation of crystalline complexes. To start with, the interactions between the two molecules should be strong enough for them to crystallize as a complex. Subsequently, the crystals should grow to sizes large enough for X-ray analysis. Obviously, complex formation would be easier if the two molecules have opposite charges. Therefore, the initial attempts were to study complexes between basic amino acids on the one hand and acidic amino acids on the other. The first crystal structure to be analysed was that of a complex between L-lysine and L-aspartic acid (L-Lysine L-aspartate). Structure determination of L-arginine L-glutamate and L-histidine L-aspartate followed. These pioneering efforts were made by T.N. Bhat who joined me as a graduate student in 1972. He has been an extraordinarily competent experimentalist and computational expert. Eventually, he settled in the US. Bhat was followed by V. Sudhakar who worked on the crystals of L-arginine ascorbate and L-serine ascorbic acid. Sudhakar retired as a Vice-President of Satyam Computers, well before the company collapsed. Dinakar Salunke, who joined in 1978, worked on L-Lysine pantothenate in addition to an amino acid - amino acid complex, for his doctoral thesis. His impactful contribution was in initiating macromolecular crystallography in Bengaluru (more about it later). He, of course, went on to become a recognized leader of structural biology.

Implications to chemical evolution and origin of life

While the work outlined above was gathering momentum, Cyril Ponnamperuma, the renowned expert on chemical evolution and origin of life, visited the Institute in 1978 on a sabbatical. Ponnamperuma was of Sri Lankan origin, had an Indian wife, was educated in England and worked in the US. Protein crystallographers like myself are naturally drawn into Darwinian evolution as each protein molecule carries the signature of its evolutionary past. However, chemical evolution leading to origin of life was new to me. I became aware of this area after listening to a series of lectures given by Ponnamperuma at the Institute. He was an extraordinarily powerful speaker who compelled attention. An assertion of his that “we are the same stuff as the stars are made of” still rings in my ears. I also took part in several discussions with him. In addition, I participated in a symposium organized by Pushpa Bhargava and P.K. Bhattacharya at Hyderabad, taking advantage of the presence of Ponnamperuma. The meeting was attended by a cross section of distinguished scientists including Yashpal and Jayant Narlikar. It was the participation in this stimulating meeting and the lectures of Ponnamperuma that prompted me to look for the evolutionary implications of our work on complexes.

"It is believed that the earth originated some 4.5 billion years ago. It must have taken several hundred million years for the earth to cool down sufficiently to support water. There is evidence to believe that life existed on earth some 3.5 to 3.8 billion years ago. Thus on a geological time scale, life must have arisen in a comparatively short span of time. The origin of life must have been preceded by chemical evolution which must have consisted of the following stages.

- Abiotic organic synthesis
- Sequence specific polymerization
- Chiral selection
- Emergence of the first self–replicating systems

No direct evidence of this phase of geological history exists. We have to employ simulation experiments, informed speculation, evidence from meteorites etc. to produce even a blurred picture of chemical evolution. The clearest part of this blurred picture is concerned with the first stage, based on the Oparin-Haldane hypothesis and Urey-Miller type experiments under conditions which simulate those that existed on the primitive earth. The experiments suggest that simple amino acids, carboxylic acids and such other small molecules could have formed in the primitive non-oxygenous atmosphere with energy inputs from UV radiation (no ozone layer existed then), lightning, volcanic eruptions etc. Similar compounds were found in several meteorites as well. Some organic compounds have been detected in interstellar space also. Thus, spontaneous generation of organic compounds, including some molecular alphabets of life, appears to be a universal phenomenon.

"Incidentally, 'the RNA world' is a popular hypothesis in relation to chemical evolution and origin of life. An RNA world may or may not have existed at some stage of the process, but could not have at the beginning. What occurs spontaneously and copiously in simulated experiments and meteorites, and to some extent in the interstellar space, are simple amino acids, carboxylic acids and other small compounds. Therefore, it is reasonable to assume that these must have been made use of in the early stages of the process.

"Once monomeric units such as amino acids are generated spontaneously, they should subsequently condense in an abiotic environment to form meaningful, sequence-specific polymers. These polymers and other relevant molecules should come together to form primitive replicating systems. In the meantime, chiral selection must also have taken place. The processes by which the primitive chirally pure self-replicating systems arose from a milieu of racemic mixtures of simple molecules, constitute the least understood link in the evolutionary history of the biosphere. The evolutionary implications of our work on complexes pertain to the possible role of molecular interactions and aggregation in these processes.

"Formation of polymers from monomers in prebiotic situation involves condensation without enzymes. The role of small condensing agents have been explored. Also explored is the condensation of amino acids adsorbed on clay particles. It has also been shown that mixtures of amino acids could polymerise, probably with non-random sequences, on heating or in the presence of condensing agents. In any case, a precondition for condensation under non-enzymatic conditions is the proximity and the favourable juxtaposition of the reacting groups. It was found that such an arrangement occurs in the crystalline complexes studied in our laboratory. That was the beginning of our interest in chemical evolution."

The arrangement referred to above, which involves head-to-tail sequence of the type ... NH_3^+-CHR-COO^-... NH_3^+-CHR-COO^-...NH_3^+-CHR-COO^-... occurs in the complexes we had by then analysed. We surmised that this peptide like arrangement could facilitate the polymerization of amino acids into peptides in an abiotic environment. I received enthusiastic support for this idea from Pushpa Bhargava, which encouraged me greatly. At a later date, I was further encouraged by S. Ranganathan and Darshan Ranganathan, then at IIT Kanpur when they carried out synthetic experiments on the basis of our proposal. After receiving whole-hearted support from Pushpa in 1980 at a meeting in Bhabha Atomic Research Centre, Mumbai, I sent a short note on our hypothesis to ***FEBS Letters***, which was straightaway accepted for publication within a couple of weeks. That emboldened me to further explore the idea. Incidentally, 1980 was an exciting year for me in terms of publications. Apart from the ***FEBS Letters*** paper, the valinomycin paper describing a novel conformation of the ionophore was published in *Nature*. Yet another interesting paper published in 1980 in *Acta Crystallographica* was a theoretical analysis of the Fourier refinement of protein structures. The analysis provided a rationale for our travails in the refinement of the structure of insulin.

In the meantime, C.G. Suresh joined me as research student. He put the work on the complexes on a firm footing. Subsequently, he had a successful career at the National Chemical Laboratory, (NCL), Pune. We have had pleasant relations with him, his wife Indu and their daughters. Detailed analysis of the available crystal structures involving amino acids by Suresh showed that head-to-tail sequences are intrinsic features of their aggregation. They exhibit a few well defined geometrical patterns (Figure 3). The geometry of amino acid aggregation with head-to-tail sequence as its central feature is influenced by the chemical nature of the side chains (Figure 4), indicating the intrinsic capacity of self-ordering of non-random sequences in non-enzymatically formed polypeptides. It was found later that head-to-tail sequences are the most important feature of peptide aggregation also. Here again, a few well defined geometrical patterns are accessed, particularly in the aggregation of dipeptides. "To sum up, amino acids and peptides arrange themselves in such a way as to promote polymerisation. Patterns which repeatedly occur in crystals tend to occur in solution as well. It was also possible to demonstrate that the proximity between the α-amino and the α-carboxylate groups is not caused exclusively by ionic forces. The geometry of and the electronic distribution in the molecules are such that the two groups tend to come close to each other. This propensity is likely to have been made use of in prebiotic polymerisation.

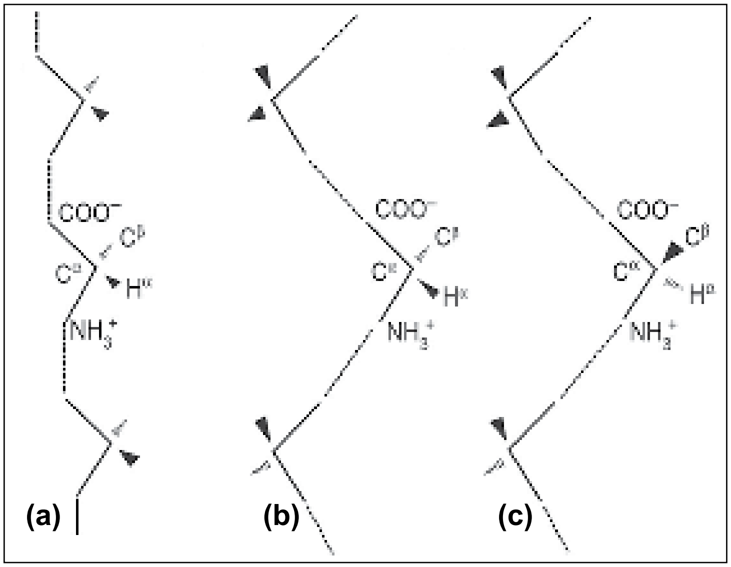


Figure 3. Schematic representation of (a) straight, (b) zigzag, and (c) DL head-to-tail sequences.

"Chirality is an intrinsic feature of biomolecules. Proteins are exclusively made of L-amino acids (and glycine which is optically neutral) while nucleic acids contain exclusively D-sugars. However, in abiotic synthesis, L-and D-isomers occur in equal measure. How were L-amino acids and D-sugars chosen in living organisms instead of D-amino acids and L-sugars? This is the problem of chiral selection. Several theories have been put forward to explain chiral selection, but none of them have found universal acceptance. Our foray into the debate was facilitated by the observation that a crystalline complex was formed when L-histidine and L-aspartic acid were put together; the same thing happened when D-histidine and D-aspartic acid were used for co-crystallization. The components crystallized out separately when L-histidine and D-aspartic acid or D-histidine and L-aspartic acid are put together in crystallization experiments. These results clearly showed that chiral discrimination could be achieved through intermolecular interactions. The choice of histidine as the basic amino acid in these experiments was fortunate. Histidine is not as strongly basic as arginine or lysine and in the case of histidine the ionic force does not overwhelm subtle chiral effects".

Since then several amino acid-amino acid complexes of mixed chirality were prepared and X-ray analysed. In general, it was found that the arrangements in complexes involving two L-amino acids are likely to lead to clean peptides. The arrangements in complexes involving mixed chirality were such as to lead to cross connections. In addition to their implications to chemical evolution, the results mentioned above show that chirality can profoundly affect molecular aggregation.

The work also clearly brought out the importance of directionality in biologically relevant ionic interactions. This directionality makes it possible to have hydrogen bonded specific interactions with a strong ionic component (Figure

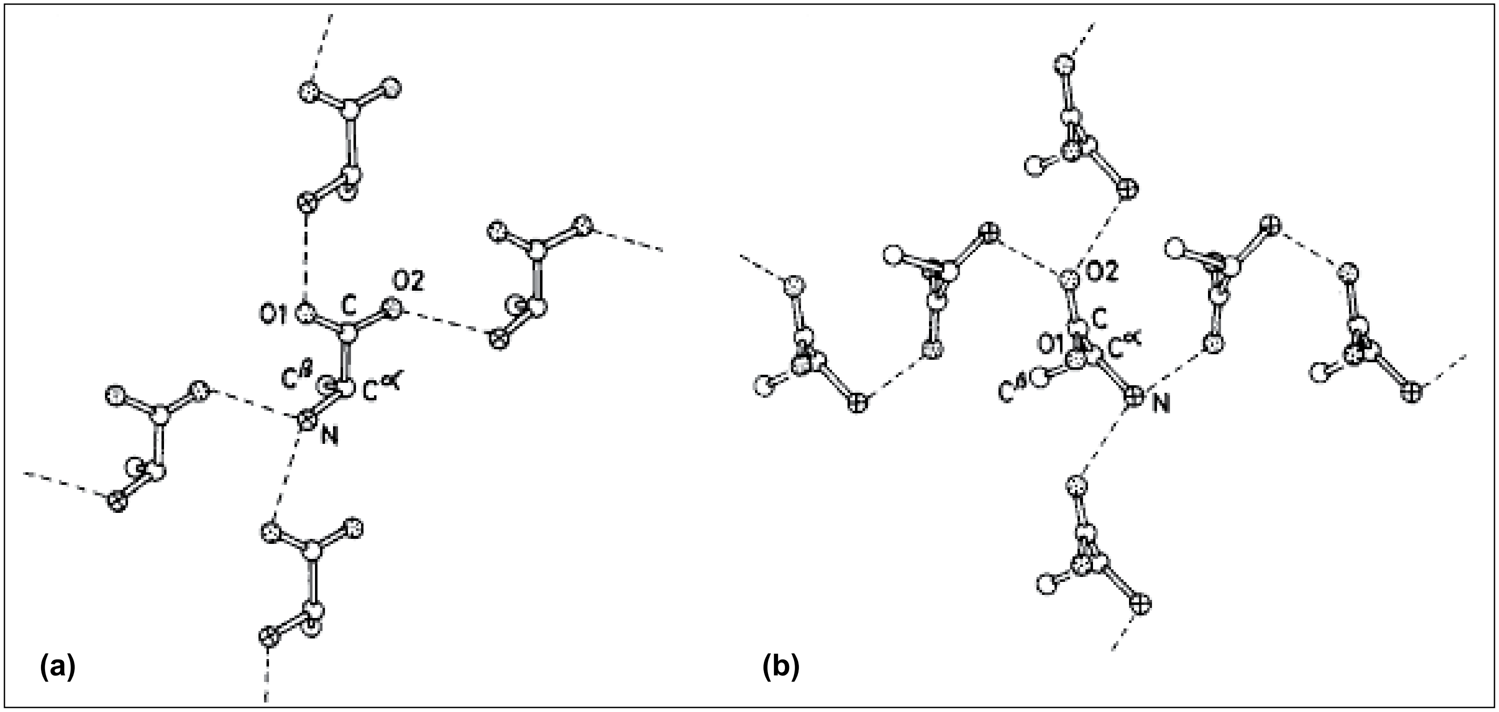


Figure 4. In the crystals of most of the hydrophobic amino acids two straight head-to-tail sequences coexist as in (a), while a straight sequence and a zigzag sequence coexist as in (b) in most crystals of the hydrophilic amino acids.

5). Biomolecules like amino acids and peptides can also form characteristic interaction patterns (Figure 6). "Thus functional groups in biomolecules and biological monomers have propensities to form specific interactions and characteristic interaction patterns. The propensities could be weak, but they exist all the same. It is a combination of weak propensities, which leads to subtility and complexity in multi-molecular systems which often self assemble. The first self-replicating systems must have arisen through self-assembly processes and the interaction propensities of the type outlined above could be important in these processes."

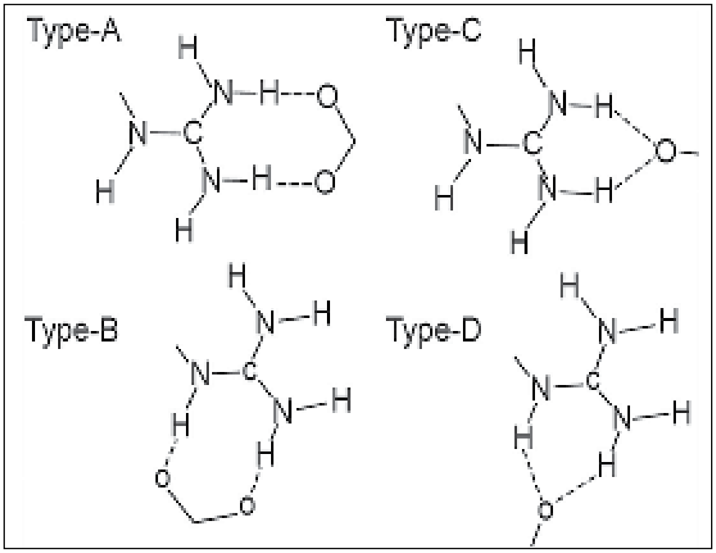


Figure 5. Schematic representations of different possible specific interactions between guanidium and carboxylate groups.

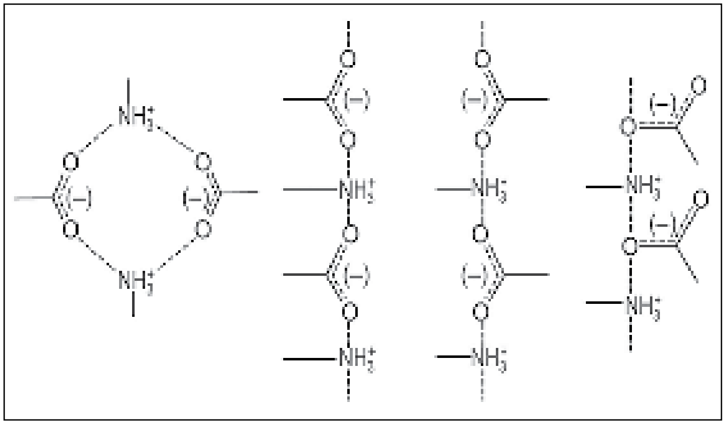


Figure 6. Schematic representations of some characteristic interaction patterns involving amino and carboxylate groups.

Deployment of students. Small molecules vs large molecules

After C.G. Suresh, Jayashree Soman, G. Sridhar Prasad and Stephen Suresh took their doctorates working on the crystalline complexes. All the three are now in the USA. Jayanthi Ramaswamy, a graduate student, worked on the project for a couple of years after which she left to join her husband in USA. All the same, she remains very attached to us. Two post-doctoral fellows who worked extensively on the complexes are Sarasija Padmanabhan and N.T. Saraswathi. I first met Sarasija at the Shemyakin Institute in Moscow when I was in Soviet Union in its dying days. She had just finished her Ph.D. and was at a loose-end. Later, she worked as a post-doctoral fellow in my lab. Still later, she studied law and is now a patent lawyer. Saraswathi completed her Ph.D. in Chennai, working on crystal growth. Her crystallography was firmed up in my lab, working on the complexes. She is now employed in Sastra University, Thanjavur. Stephen Suresh completed his Ph.D. programme in the first half of 1990s. By that time, we were active in macromolecular crystallography as well. Nearly half the students used to work on macromolecular crystallographic problems, while the other half worked on the complexes. Stephen was among the latter group. Although bright, I found a lack of enthusiasm on the part of Stephen in his research. I was naturally concerned about it. Raghavan Varadarajan, then a young faculty member, was the one who enlightened me on the reason for Stephen's indifference. He felt, probably correctly, that small molecules are less glamorous than proteins and hence felt deprived. I was sensitive to his sentiments and arranged for him to work on a protein, soon after he finished his Ph.D. work, before he left for his post-doctoral stint in Seattle. I fondly remember how Stephen looked after me, when I was in Seattle in 1996 for a Crystallography Congress.

After the Stephen Suresh episode, I stopped assigning work on the complexes as a Ph.D. problem to students. All my subsequent students worked on proteins for their Ph.D. degrees. However, I used to ask them to work on the complexes, on the side, primarily as part of crystallography training. The volume of information on the complexes produced through this route has been substantial.

Supramolecular association involving amino acids, peptides and carboxylic acids

"In the early stages of the work on crystalline complexes, the emphasis was primarily on those among amino acids and peptides themselves.

Then it was felt necessary to also include in the effort other small biomolecules that are believed to have existed in the prebiotic milieu. The emphasis in this respect was particularly on small carboxylic acids. In view of the relevance of the work to supramolecular association, eventually the programme was expanded to encompass a series of carboxylic and dicarboxylic acids. Complexation and X-ray studies of these compounds with the three basic amino acids and a couple of peptides were attempted. Wherever possible, complexes of L and D isomers of the same amino acid were studied simultaneously. X-ray studies on these complexes enriched the leads provided earlier on head-to-tail sequences, chiral discrimination, specific interactions and interaction patterns. Furthermore, they produced a rich fare of results on molecular sociology and supramolecular association".

"The crystal structures of the complexes of histidine and glycolic acid were particularly interesting in relation to chiral separation. Crystallization experiments involving DL-histidine and glycolic acid yielded not only crystals of DL-histidine glycolate but also those of L-histidine glycolate and D-histidine glycolate. To the best of our knowledge, this is the first example of chiral separation achieved through interaction with an achiral molecule. Furthermore, the crystal structures of DL-histidine glycolate and L-histidine glycolate provide a structural explanation for this separation. In the former, the unlike molecules aggregate into separate alternating layers. The crystals of L-histidine glycolate is made up of columns consisting of tightly interacting histidinium and glycolate ions. Here the interaction between the molecular ions within the column is stronger than that between columns. Thus the interaction between unlike molecules is stronger when the amino acid is a pure isomer than when it exists as a racemate. That appears to be the reason for the observed chiral separation."

Another interesting observation was related to the relation among aggregation, stoichiometry and the ionization state. For example, succinic acid exists in four different ionization states in its complexes depending on the nature of the aggregation pattern (Figure 7). Stoichiometry in the complexes also exhibit considerable variation (Table 1). It was also found that in spite of the differences in the chemical structure of the carboxylic acids used, the aggregation patterns in their complexes exhibit common features (Figure 8). The different aggregation patterns observed in the crystal

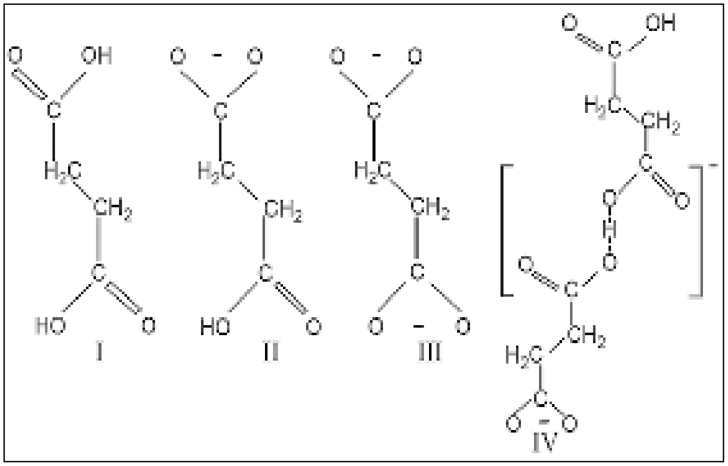


Figure 7. Different ionization states of succinic acid observed in complexes.

Table 1. Composition of complexes involving succinic acid

Complex with	I	II	III	IV	H_2O
DL-arginine	–	–	1/2	–	2
L-arginine	1/2	–	1/2	–	1
DL-lysine	1/2	–	1/2	–	–
L-lysine form I	–	1	–	–	–
L-lysine form II	1/4	–	1/2	1/4	–
DL-histidine	–	–	1/2	–	2
L-histidine	–	1	–	–	3
DL-proline	1/2–	–	–	–	–
Glycyl-L-histidine	–	1	–	–	1

structures could also be elegantly rationalised in terms of the chemical nature and the size of the component molecules.

Involvement with ISRO

ISRO naturally has an interest in exo-biology. The 1978 Hyderabad meeting, referred to earlier, was supported by ISRO. ISRO also played a pivotal role in putting together a vibrant programme on chemical evolution, evolution of earth, evolution of atmosphere etc. The participants in the composite programme included geologists, atmospheric scientists, chemists, structural biologists etc. The discussions within the groups stimulated us and enhanced our vision and understanding. They led to research resulting in many significant insights.

My association with ISRO was not confined to the specific programme mentioned above. I have only seen Vikram Sarabhai from a distance. I knew Satish Dhawan intimately. I had good rapport with U.R. Rao. K. Kasturirangan is a personal friend. I knew G. Madhavan Nair only slightly. I have been reasonably close to K. Radhakrishnan. In fact, I have often been overwhelmed by the consideration he has shown to me. I have had no occasion to work with the subsequent ISRO Chairmen.

I was a member of the Advisory Committee on Space Science (ADCOS) of ISRO for a number of years. That provided me with an opportunity for interacting with a large number of space scientists as well as officers at ISRO headquarters. That was an altogether pleasant experience. I recall Professor Hiren Mukherjee, the great parliamentarian, addressing us at the Institute in the mid-1970s after a visit to ISRO. He said "today I saw the smile of young India". One leading scientist with whom I became close through work with ADCOS was A.P. Mitra. I had known and worked with him earlier, when he was the Director General of CSIR. The relationship became closer when he was the Chairman of ADCOS and I a member.

Guest who stayed

When I started the effort, I considered the work on crystalline complexes only as a bridging operation until I was able to start macromolecular crystallography in India. However, the evolutionary implications of the work and the association with ISRO gave an entirely new dimension to the problem. Chemical evolution and origin of life are not issues which can be settled through usual

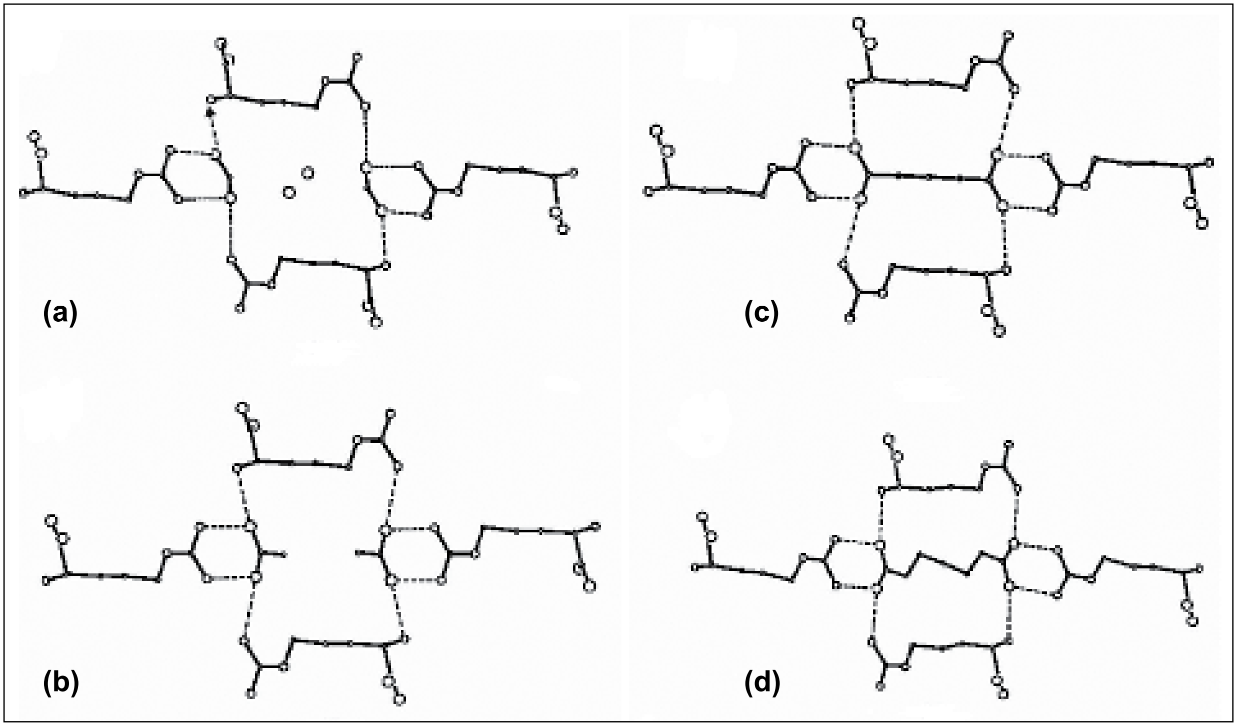


Figure 8. A basic element of amino acid aggregation in DL-arginine complexes with (a) formic acid, (b) acetic acid, (c) glutaric acid, and (d) pimelic acid. Adapted from Acta Cryst. **B59**, *641-646, 2003*

experimentation. The traces of the events that took place four billion years ago are extremely tenuous. Most of the hypotheses are in the form of informed guesses. From whatever evidences we have, simulated experiments and plain common sense, we have to construct a likely scenario which cannot be obviously proved or disproved through experimentation, as chemical evolution and origin of life on earth cannot be repeated in the laboratory. However, construction of likely scenarios stimulates the mind and leads to significant experimentation. In our case, the distant objective of exploring chemical evolution and origin of life led, inter alia, to exciting results on supramolecular association and its consequences. The wonderful people with whom I had the opportunity of interacting through the implementation of the programme, made the enterprise all the more interesting. Consequently, we pursued the programme even after macromolecular crystallography studies were well established in the laboratory. The programme on crystalline complexes was wound up only after I formally retired.

9

INDUCTION INTO THE BIOLOGY COMMUNITY

My formal education in biology stopped at the 10th standard. I found the subject far too descriptive and dull. The requirement for drawing the contents of a cell was well beyond my artistic talents. I did not have the heart to dissect a mouse either. My formal education in chemistry extended up to the pre-university level. Since then, my education was wholly in physics with of course a smattering of mathematics. Once I started working in crystallography, I began to be familiar with chemistry, particularly, structural chemistry. My entry into crystallography coincided with the beginning of the heroic era of biological crystallography. Modern biology, of which biological crystallography forms part, is of course very different from the biology I studied in school. Structure of biomolecules, especially proteins, excited me. My transition from physics to biology was greatly facilitated by my work in Dorothy Hodgkin's group. The ambience of the lab was such that one imperceptibly acquired information and knowledge. Of course, I was only following the path shown by greats like Max Delbruck, Francis Crick, G.N. Ramachandran etc., in moving from physics to biology.

In India, crystallography was mostly practised by physicists. Therefore, I had very little interaction with biologists. The molecular biology group at the Institute referred to earlier, helped establish relations with biochemists and molecular biologists on campus. These interactions were taken a step forward when I got involved with work on chemical evolution and origin of life. I have already referred to the encouragement I received from Pushpa Bhargava. I cherish the life-long association I had with Pushpa. He was indulgent in his affection for me even when we had bitter differences. Another person whom I came to know during this period was John Barnabas who was then working in a remote centre in Maharashtra, viz., Ahmednagar college. He produced outstanding work pertaining to evolution using very limited facilities. Over the years I grew very close to John who was almost like an elder brother to me. Pushpa and John were the two B's of the five B's of Indian biochemistry, the others being (B.K.) Bachhawat, (B.B.) Biswas and (D.P.) Burma. I came to know closely the remaining three B's and many other leading biochemists of India.

Mahabaleshwar Seminars on Modern Biology were a vehicle that helped me interact with a cross-section of Indian biology. The seminars were held in the property of Ahmednagar College at the resort town during off-peak season every year. The seminars were sponsored by Ahmednagar College, Tata Institute of Fundamental Research (TIFR) and Indian Institute of Science and commenced in the mid-1970s with John Barnabas and Obaid Siddiqi as the main organizers. I participated in a few of them on structural biology and evolution, starting from 1978. The stay at Mahabaleshwar was pleasant and exhilarating with so much scenic beauty around. The Deccan Traps in the neighbourhood made a profound impression on me. The participants lived together and the atmosphere was homely. The proceedings of the seminars used to be informal and scientifically intense. The main meetings used to be held in an unused chapel. That added to the very special ambience of the Mahabaleshwar seminars.

I established many enduring relationships during the seminars. It was at Mahabaleshwar that I had the first significant interactions with Obaid Siddiqi. Obaid, of course, was a renowned scientist. He was much else, above all, a sterling human being. He came from an aristocratic lineage and was grace personified. Although both of us had left active politics, we had very similar leftist backgrounds. Obaid was much senior to me, but he never let me feel it. My rapport with him continued till he passed away. We worked together on a few occasions. Another senior scientist I came to know well through Mahabaleshwar seminars and meetings on chemical evolution and origin of life, was M.S. Chadha of BARC. Although Chadha was much senior to me, I developed a close and easy relationship with him.

Perhaps, the most important avenue which helped me to embed myself in the biology community of India was the Guha Research Conference (GRC). GRC was established in 1960 by a group of then young Indian biochemists. The first few meetings used to be held on the sidelines of the annual meetings of the Indian Science Congress. Eventually, it was registered as a Society. GRC is named after Bires Chandra Guha, a distinguished professor of Biochemistry in Kolkata. GRC meets every year in a secluded, often scenic location. Participation of family members is encouraged. Discussions in the scientific sessions are characterized by extreme informality. Visual aids such as slides are not allowed. Participants are encouraged to interrupt the speaker whenever they choose to. Ample avenues exist for close interactions among participants and their families. On the whole, GRC meetings provided a high level of intellectual stimulation and camaraderie among participants.

By the time I got elected to GRC, the original group of young biochemists had become leaders of science in the country. My first GRC meeting was at Kottayam/Alleppy in 1980. This meeting was organized by Paul Vidyathil, a distinguished but under-rated biophysical chemist who was at the Indian Institute of Science. The second meeting was at Srinagar in 1981. The conveners, I think, were D. Balasubramanian (Balu) and Mahtab Bamji, both of whom became our close life-long friends. Kalyani and Devi also accompanied me to Srinagar. In addition to the scientific stimulation that the meeting provided, the stay in Kashmir was an overwhelming experience. The third meeting that I attended, again along with Kalyani and Devi, was at Goa. U.W. Kenkare was the organizer of the Goa meeting. One thing I remember about Kenkare is his resemblance to EMS! The Goa meeting was again scientifically stimulating. We also got to visit many interesting locations of Goa. I have, of course, visited Goa many more times, including for attending a general meeting of the Indian National Science Academy (INSA) at which I assumed its Presidentship. However, it is the 1982 visit that would first come to mind when I think of Goa. I attended a few more GRC meetings till mid-1990s, all very pleasant and stimulating. By then, I had truly become part of the Indian biochemistry/molecular biology community.

It was through the GRC meetings that we came to know D.P. Burma (Debida) and his wife Maharani Chakravorty. They have been almost family to me and I have interacted with them in several ways. Debida has been a constant source of support and encouragement. Another distinguished scientist whom I knew even before I was elected to the GRC and who deeply touched my professorial life was B.K. Bachhawat. For one thing, he was among the pioneers of lectin research in the country and provided inspiration for my work on the structural biology of lectins. He was a simple person, but commanded loyalty. I and many in my generation, like Asis Dutta, Sandeep Basu and C.M. Gupta, were deeply attached to him. He had a self deprecating humor. He was a poor speaker and he quoted one of his students saying after a lecture of his, "you are improving sir"! During his time, he wielded considerable influence in the Indian biology community. Another distinguished leader of science I came to know through GRC was G.P. Talwar. I had several occasions to interact with him in later life. He also encouraged me greatly.

M.K. Chandrashekaran, who worked on circadian rhythms, appeared on the scene almost at the same time as I did. The subjects of Chandrashekaran's study at that time were bats which lived in caves near Madurai. We often used to call him "batman". Chandrashekaran worked on the behavior of whole organisms while I was a reductionist working on molecules. Both of us were active members of GRC. We respected each other. We received support and encouragement from the same set of biologists, the names of some of whom have already been mentioned. That was an indication of the kind of generous and tolerant ambience that prevailed in the biology community.

Modern biology in India essentially emerged in the post-independent era. Subjects like physics and chemistry have a much longer history and had well established leaderships. Long history also carried with it some baggage which could be detrimental to the free play of creativity. No such baggage existed in India in the case of modern biology. The community was still evolving when I entered it. Although I was from a different background, I was embraced with affection and enthusiasm by the members of the community. Eventually, over the years, particularly through my involvement with academies and government departments, my domains of interest transcended disciplinary borders and embraced Indian science as a whole.

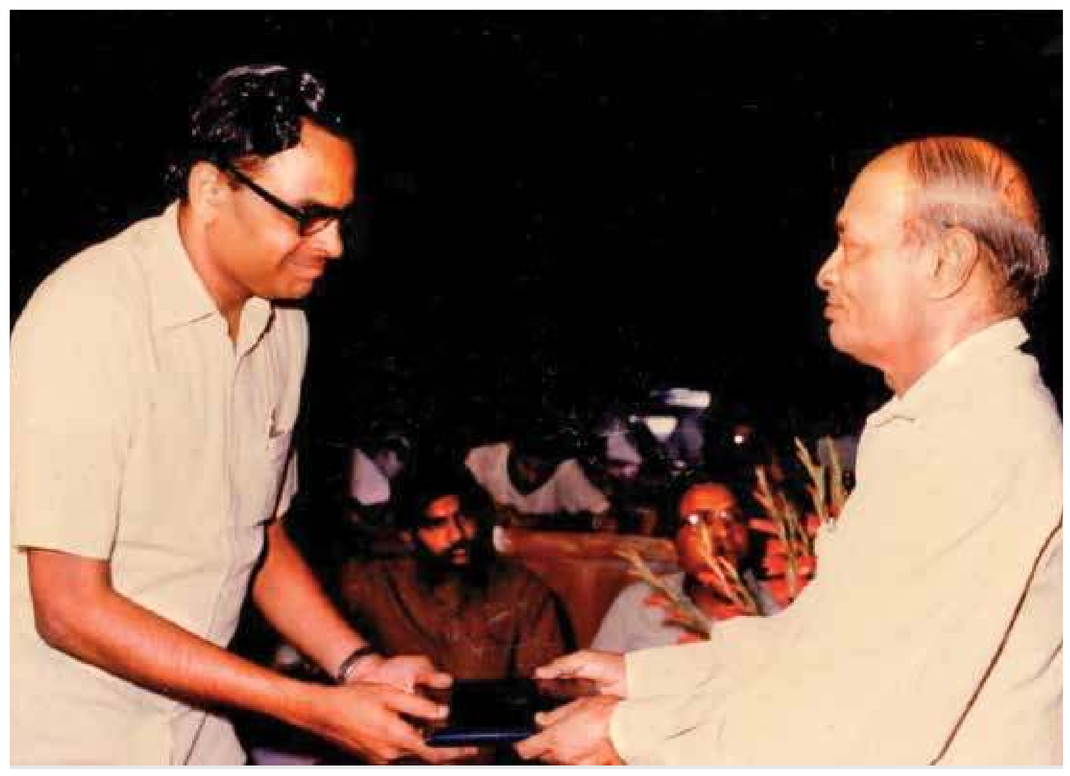
10

INITIATION AND DEVELOPMENT OF MACROMOLECULAR CRYSTALLOGRAPHY IN INDIA. REALIZATION OF A DREAM

India has a long tradition in X-ray crystallography starting with the work of K. Banerjee in Kolkata in the 1930s. GNR and his colleagues gave a head-start for India in foundations of crystallography and molecular biophysics. However, their efforts in molecular biophysics (structural biology) were primarily computational in nature. GNR wanted to initiate in the country macromolecular crystallographic studies which are central to modern biology, but the time was not ripe for it. A few Indians, notably Gopinath Kartha, were involved in early protein crystallography studies abroad. However, I was the first trained macromolecular crystallographer to return to India in 1971. In the absence of the wherewithal for initiating the area in India, as indicated earlier, I got involved in a somewhat novel programme on small biomolecules. In the meantime, my friend, K.K. Kannan, who worked on the crystallography of carbonic anhydrase in Uppsala, returned to India in 1978 and joined BARC. By the end of the 1970s there were two of us trained macromolecular crystallographers in India.

Exploratory efforts

Although my small molecules programme had begun to yield interesting results, I was constantly looking for opportunities to initiate macromolecular crystallography. In the second half of the 1970s economic situation in India began to improve, thanks mainly to the Green Revolution. Importing equipment was still a problem, but not as formidable a problem as it used to be. I have



Receiving Bhatnagar Prize from HRD Minister P.V. Narasimha Rao.

Receiving the FICCI Award from Prime Minister Deve Gowda.

Receiving the first CSIR-G.N. Ramachandran Gold Medal from Prime Minister Manmohan Singh.

A 1999 photograph featuring three former students who are now leaders of science.
Back row (R to L) : Dinakar Salunke, Shekhar Mande, Vijayan and T.P. Singh

C.G. Suresh with Vijayan, Eleanor Dodson, Devi at home. As a student Suresh systematized the work on crystalline complexes involving amino acids and peptides, before moving on to Macromolecular Crystallography.

Rahul Banerjee and Vijayan at home. Rahul as a student played a critical role in the structure determination of Peanut lectin, which was widely noticed.

R. Sankaranarayanan with Pushpa Bhargava and Vijayan. Sankaranarayanan was the student involved, along with K. Sekar in the structure solution of Jacalin in the mid-1990s. The work on Peanut lectin and Jacalin established the Bengaluru laboratory as a leading centre of Macromolecular Crystallography.

already referred to the procurement of two decent sealed tube X-ray generators which we christened as HH1 and HH2 (HH standing for High Hope). We could also procure precession cameras and a manually operated microdensitometer. In the mid-1970s, a four circle diffractometer, primarily meant for small molecules work, was also installed at the Institute as a central facility. Thus, we had the basic minimum facilities for carrying out preliminary X-ray studies on proteins crystals.

That was the period when most of the structural studies on proteins were carried out almost exclusively through collaboration. Crystallographers carried out structural work while the material was provided by biochemists. The biochemists at the Institute were enthusiastic, but no firm collaborative arrangement could be set up. At some point, I had the audacity to contemplate taking up myself the isolation and purification of proteins. In fact, I procured a walk-in cold room and fraction collector for the purpose. In the meantime, we also devised plans for working with commercially available proteins.

A one-off effort undertaken during this period involved exploring additional binding sites in the well-known enzyme lysozyme. This problem was brought to my attention in the late 1970s by Shantoo Gurnani of BARC, who was introduced to me by Pushpa Bhargava. Gurnani was an interesting personality. She belonged to Sindh. During partition, when she was a young lady, she fled to India as a refugee. She was then substantially uneducated. Through determination and hard work, she got herself educated and reached the position of a senior scientist at BARC. She had already carried out solution studies on the interactions of lysozyme with the dyes bromophenol red and bromophenol blue, along with G. Krishnamoorthy and B.S. Prabhananda of TIFR. The dye-bound enzyme was still active against the polysaccharide, but not against the bacterial cell wall. This suggested the presence of at least one other binding site, in addition to the well characterized cleft in the enzyme which binds the polysaccharide. The dyes presumably blocked the additional binding site(s). The idea was to characterize this additional binding site(s) using X-ray crystallography.

The problem referred to above did not require any serious biochemical effort. Lysozyme and the dyes were commercially available at low cost. X-ray facilities available at that time were just enough to carry out preliminary crystallographic studies. To start with, my student H.M. Krishna Murthy worked on the problem and the very preliminary results were presented as a poster in the Ottawa Crystallography Congress in 1981. The work was carried forward by B. Veerapandian, a Faculty Improvement Programme student, with the help of Dinakar Salunke. A 5.5Å resolution data set on the lysozyme-bromophenol red complex was collected on the diffractometer. 15° procession photographs of different projections were recorded and the intensities measured using a manual microdensitometer. On the strength of this limited amount of data, we published the structure of the complex in 1985. I was extremely nervous about our being proved wrong. I breathed easy only when the conclusion was proved correct by my student Madhusudan in the early 1990s using high resolution data with the aid of modern facilities. Veerapandian's Ph.D. thesis was on the additional binding site on lysozyme. He is now a scientific entrepreneur based in USA.

We initiated yet another project using commercially available proteins, by taking a leaf out of our work on crystalline complexes of small biomoleucles. Ribonuclease A and insulin are two very well studied proteins. Ribonuclease A is highly basic whereas insulin is slightly acidic. At a pH of about 8.0, ribonuclease A would be positively charged and insulin, negatively charged. We thought we could probably make a complex of the two at that pH. Detailed crystallization experiments carried out by Dinakar did not result in a complex. However, he obtained a new crystal form of ribonuclease A. This new form yielded slightly different unit cell dimensions and solvent content in different experiments. To start with, we were baffled. We could grow the new crystal form even in the absence of insulin. The precipitant used in crystallization was acetone which is very volatile. Therefore, the control of water content around the crystal mounted in a capillary was difficult. The variation in the water content led to transformation to a related crystal form.

Unlike crystals of small molecules, protein crystals typically contain 50% water. In the absence of this water, the crystal collapses. Therefore, traditionally the crystal used to be mounted along with a small amount of the crystallization solution in a thin walled capillary. The relative humidity around the crystal is then about 100%. The relative humidity around a crystal can be systematically varied by introducing appropriate salt solutions in the capillary. Guided by the serendipitic observation on the new crystal form of ribonuclease A, this is precisely what we did on different crystal forms of the well-known enzymes ribonuclease A and lysozyme. We observed that many crystals undergo reversible water-mediated transformations with change in the water content of the crystals, when the relative humidity of the surroundings is systematically varied. Diffraction patterns suggested that water mediated transformations are accompanied by some changes in the molecular structure as well. In addition to Dinakar, Veerapandian and a new graduate student, R. Kodandapani also participated in the gross characterization of water-mediated transformations using preliminary X-ray data. The results were published in 1985 as a paper in *Acta Crystallographica*.

The most significant development during the exploratory phase was the initiation of structural biology studies on lectins. In late 1978, I met A. Surolia in Hyderabad, on the sidelines of a conference, using the good offices of my friend and colleague S.K. Podder. Surolia had just obtained his doctorate working on lectins under the supervision of B.K. Bachhawat at Christian Medical College, Vellore and had moved along with Bachhawat to what is now called the Indian Institute of Chemical Biology (IICB), Kolkata. Surolia was intensely interested in structural biology and was happy to collaborate with me. That was the beginning of decades long collaboration and friendship between us.

Lectins are often described as multivalent carbohydrate binding proteins of non-immune origin, which specifically recognise different sugar structures. Although first discovered in plants, they were subsequently found in animals, algae, bacteria, fungi, yeast and viruses as well. Most recently, in our laboratory, we established the presence of lectins in archea as well. Lectins are important proteins found in all domains of life and have the property of specifically recognizing different kinds of sugars (carbohydrates). Sugars and their polymers, viz., oligo saccharides and polysaccharides, are widely distributed in nature. They often occur in combination with proteins and lipids. Sugars can polymerise in different ways leading to structural components like cellulose and food materials like starch. Sugars began to receive increased attention with the realization that most of the recognitive processes on the cell surface are mediated by sugars. Consequently, lectins also began to receive considerable attention as they are quintessential sugar-binding molecules with recognitive function. Surolia and I entered the field when structural biology studies on lectins, indeed other kinds of studies as well, were at an incipient stage.

We started our work on the structural biology of lectins with attempts to crysallize the *Ricinus communis* Agglutinin (RCA). We could not crystallize the protein, in spite of repeated attempts. We had better luck with peanut agglutinin (PNA) which could be readily crystallized in early 1981. That, to an extent, facilitated the appointment of Surolia as an Assistant Professor in MBU in the same year. The crystallization and the preliminary X-ray data of PNA were published in *Journal of Molecular Biology* in early 1982, with Dinakar Salunke, Islam Khan, Surolia and myself as authors. That marked the beginning of structural biology studies on lectins in the country. To a substantial extent, the publication of that short paper also marked the launching of serious macromolecular crystallography studies in India. Using X-ray and biochemical data, we could establish the rough quaternary association in PNA as described in a paper in *Journal of Biological Chemistry* in 1985. With that the exploratory phase of the work on lectins came to an end.

National mandate, technological issues

By late 1981 and early 1982, the exploratory studies had begun to show promise and it was time to think ahead. The DST had by then further rejuvenated through the historic Baroda seminars. I recall visiting the DST office in New Delhi and having a discussion with P.J. Lavakare. He was very friendly and positive. That was my first introduction to Lavakare. I had much to do with him in my later career. To me, he remains an ideal science administrator and a wonderful human being. That was also the period when a change of guard was taking place at DST. S. Varadarajan took over as Secretary, DST from M.G.K. Menon in 1982. Both of them subsequently turned out to be important influences in my life.

In the meantime, V. Sasisekharan and colleagues had initiated fibre diffraction studies of DNA, as a follow up to their outstanding work on the variability of the structure of DNA. Until the second half of the 1970s, DNA used to be considered as a nearly monotonic double helix. This belief persisted even in the early 1980s. I recall a conversation with Aaron Klug, the Nobel Laureate and future President of the Royal Society, when I visited Cambridge in1981. During the conversation, he said “I greatly respect Sasisekharan, but DNA is a right-handed double helix with approximately ten base pairs per turn”. Now we know that DNA can assume a variety of secondary structures, many of which are functionally important. It was Sasisekharan who was most responsible for, so to say, opening up the structure of DNA. Sasisekharan’s colleagues included Manju Bansal and Samir Brahmachari who were appointed as faculty members during 1981-82. Samir primarily provided biochemical support to Sasisekharan, in addition to pursuing his own work.

There was considerable overlap between the facilities required for protein crystallography and fibre diffraction studies. Therefore, as indicated earlier, Sasisekharan, myself, Surolia and Samir together submitted in 1982 a large project proposal to DST under their Thrust Area Programme. The proposal encompassed protein crystallography studies and fibre diffraction of DNA. The proposal was duly considered by the concerned Programme Advisory Committee (PAC) and the Apex body called the Science and Engineering Research Council (SERC). The PAC was chaired by N. Seshagiri, who was a leader of the IT revolution in India and, among other things, the Founder Director General of the National Informatics Centre (NIC). He, a personal friend of mine, also had keen interest in biophysics. Varadrajan had by then become the Secretary of DST and chaired the SERC. The officers who were involved in handling the proposal included, in addition to Lavakere, Ashok Jain, who subsequently became the Director of the National Institute of Science, Technology and Development Studies (NISTADS) and Sulbha Gupta to whom reference has already been made in the context of an activity when she was the student of the Institute.

Our proposal was received enthusiastically by the PAC and SERC. Primarily at the instance of Seshagiri and Varadarajan, an understanding was reached that our group at Bengaluru would function as a national nucleus for the development of macromolecular crystallography in India. This is the mandate that we have tried to fulfill over the decades, in addition to carrying out our own scientific research in Bengaluru. The project was sanctioned in 1983. Critical support for pursuing serious macromolecular crystallography studies was now available. The facilities created then were substantially augmented around 1990 with the addition of a position sensitive detector (Area detector), with the support provided by MBU and DST. The setup was then formally designated as a national facility. As mentioned earlier, the only condition that I attached when agreeing to do so was that it should not come in the way of other laboratories procuring similar instruments. In fact, over the decades, I positively intervened to enable other laboratories in different parts of the country to acquire major X-ray facilities. In the early years, we also used to conduct seminars periodically for macromolecular crystallographers in the country. That and the use of common facilities helped in promoting coherence in the community.

From 1983 till date, DST has continuously supported the Bengaluru facility. Sasisekharan retired in 1993. Support was obtained for some protein crystallography projects from other agencies. However, the lectin programme all along remained with DST. During a long period, that used to be considered as one of the flagship programmes of DST. We have all along received unstinted support from successive Secretaries of DST and Chairmen of the PAC. The support and help we received from the officers of DST has been overwhelming. In addition to those who have been named earlier, I gratefully remember Rao Aiyagari, R.C. Srivastava, B. Hari Gopal, B.P. Singh, Praveen Kumar Somasundaram, Rita Gupta, and B.P. Singh etc.

With the handsome grant provided by DST, we could setup a reasonably good macromolecular X-ray crystallographic facility at MBU in the mid-1980s. The method of choice for X-ray intensity data collection was then oscillation photography using rotating anode X-ray generators coupled with computer controlled microdensitometry. Data collection from a given protein typically took several months and often involved dozens of crystals. In advanced countries, powerful synchrotron sources had become the norm for data collection. Using synchrotron radiation, data could be collected in a few days using one crystal. The absence of ready access to synchrotron sources left us at a disadvantage. The availability of position sensitive detectors from 1990 onwards substantially changed the scenario. Using these devices and rotating anode X-ray generators, data from a protein could now be collected in a couple of days. Of course, if synchrotron sources were used instead of rotating anode generators, the same data could be often collected within minutes. However, considering the time taken for analysis, a few days for data collection appeared reasonable. Absence of ready access to synchrotron facilities was still a problem. But with the availability of a position sensitive detector, it was not as formidable a problem as it used to be before. As mentioned earlier, the first position sensitive detector was installed in Bengaluru around 1990. Over the decades, a large number of position sensitive detectors of different kinds were installed in various parts of the country.

Inadequate access to computational facilities in the 1980s and 1990s, on account of sanctions imposed on India, have already been referred to. For a decade or more, this was a debilitating problem in the development of macromolecular crystallography in the country. Eventually, with the rapid advances in computer technology, this also ceased to be a problem. Thus, major technological bottlenecks in relation to macromolecular crystallography were removed by the turn of the century. Inadequate access to synchrotron sources, particularly the absence of an Indian synchrotron facility, however, remained a serious lacuna.

Structural biology of plant lectins, national impact

The programme on the structural biology of lectins had its origin in the meeting between myself and Surolia in 1978. Subsequently, K. Suguna, who had worked earlier on a lectin as a post-doctoral fellow in the US, joined the effort. Since then, the three of us have been continuously involved in the programme which has now lasted more than four decades, with uninterrupted support from DST. We entered the field at a time when crystallographic work on lectins had just been initiated in the world. Three dimensional structures of only conconavalin A (Con A) from jack bean and wheat germ agglutinin were available. The early entry into the field enabled us to make important, globally competitive contributions in the area. In addition, structural studies on lectins, particularly plant lectins, turned out to be an important vehicle for the initiation and development of macromolecular crystallography in India.

Personal rapport among the participants is very important in a successful long range collaborative programme. In the present case, the rapport extended to the families as well. Surolia's wife Namita, a dear friend, is also a scientist. Their daughter, Ira, is only a couple of years younger than Devi. Suguna's husband Durga Rao has been a distinguished faculty member of the Institute. Kalyani and I have had very pleasant interactions with him. We have watched their daughter Hima, growing up.

As mentioned earlier, our first efforts in the programme were on the structure solution of PNA. The tetrameric PNA molecule was large even by global standards in the early 1980s. The available experimental and computational facilities were then inadequate to deal with such a large structure. In addition, it turned out later that PNA had an unusual quaternary structure (arrangement of the four subunits in the molecule). Our early efforts were to solve the PNA structure using its similarity to the structure of tetrameric Con A. The efforts failed. The main success during the first decade of the programme was in crystallizing and characterizing important lectins, which formed a spring board for further detailed structural work. Late V. Dhanaraj, Rahul Banerjee and R. Sankaranarayanan made notable contributions to the crystallization efforts. Our inability to determine the structure of a lectin in a reasonable time frame caused a great deal of frustration. It is a tribute to the generosity and understanding of colleagues involved with DST that they kept faith with me during that difficult period. Eventually, the structure of PNA was determined by the multiple isomorphous replacement method in the early 1990s. This was made possible by the use of the newly acquired area detector and the arrival of a larger computer at the Supercomputer Education and Research Centre of the Institute. Key contributions to the structure solution came from Shekhar Mande and Rahul Banerjee, both of whom were then Ph.D. students. Dhanaraj and postdoctoral fellows V. Ganesh and Kalyan Das, also contributed to the work. PNA has an unusual quaternary structure (Figure 1) and hence attracted considerable attention. The first definitive structural paper was then published in the *Proceedings of the National Academy of Sciences, USA* in 1994. This was closely followed by the structure analysis of jacalin, one of the two lectins in jackfruit seeds, by R. Sankaranarayanan, K. Sekar, a post-doctoral fellow, and others. The structure revealed a new lectin fold (Figure 2) and the results were published in *Nature Structural Biology* in 1996. These two major structure determinations, which attracted widespread global attention, truly launched the structural biology programme on lectins. We have never looked back since.

Until comparatively recently, our lectin programme was almost exclusively concerned with plant lectins. The basic architecture of a subunit, called the tertiary structure, is often characterized

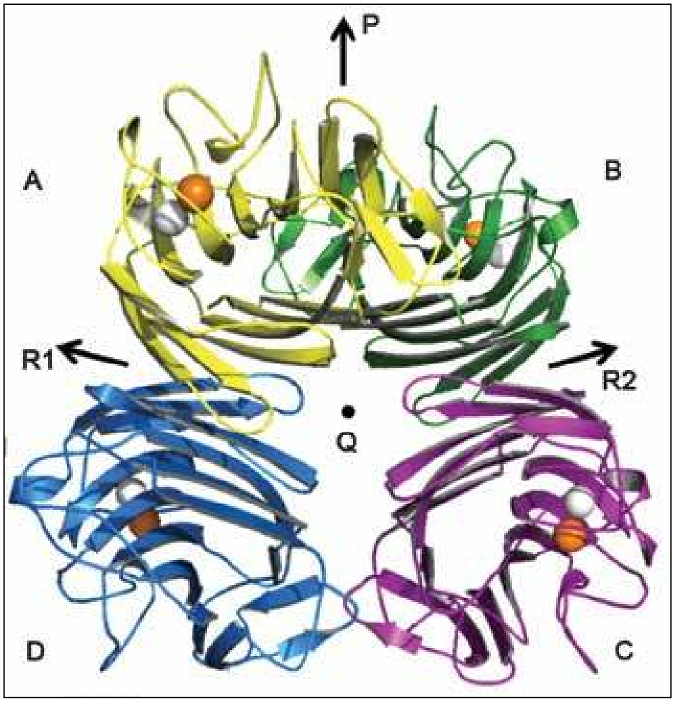


Figure 1. Tetrameric molecule of peanut lectin. The four subunits are colored differently. The molecule does not have four fold or 222 symmetry.

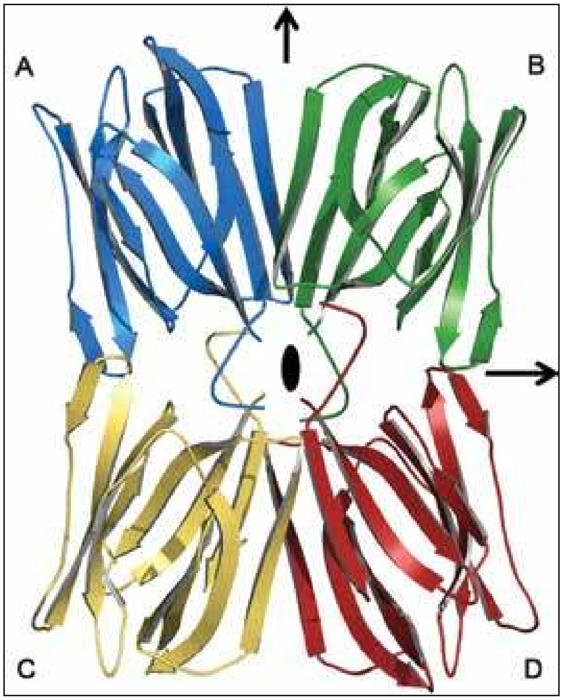


Figure 2. Molecular structure of tetrameric jacalin. The four subunits are colored differently.

by the way the polypeptide chain is folded to form a three-dimensional unit. The total number of folds is believed to be a little over a thousand. They form the basic modular units of protein structure. It is their elaboration and combinations that lead to hundreds of thousands of independent proteins in nature.

Plant lectins can be classified in terms of the folds they adopt. Con A, the first lectin to be studied crystallographically, has what came to be known as the legume lectin fold. The structure of wheat germ agglutinin was determined next in the latter half of the 1970s. It has what is described as the havein fold. Type II ribosome inactivating proteins (RIPs) have a lectin chain and a catalytic chain, connected by a disulfide bridge. In the 1980s, it was discovered that the lectin chain is made up of two β-trefoil fold domains, through the structure analysis of ricin from *Ricinus communis*. The X-ray analysis of snow-drop lectin, in the early 1990s, revealed the β-prism II fold. Our work on jacalin in the mid-1990s brought to light a fifth lectin fold described as β-prism I. Most of the plant lectin structures analysed so far have one of the five folds mentioned above. Within the framework of a few folds, a variety of different lectins with varying functions are generated through differences in quaternary association and sugar specificity resulting from variability of amino acid residues in the extended sugar binding sites.

We have dealt with four of the five categories based on folds mentioned above (Figure 3). Over a period of close to four decades, our efforts on plant lectins have involved 90 crystal structures on 12 lectins and their complexes. The structure and function of PNA, a tetrameric legume lectin, has been characterized using 21 independent crystal structures, over a period of two decades. In addition to the names already mentioned, the students who worked on PNA include R. Ravishankar and Kundhavai Natchiar. Moses Prabu, N. Manoj, Kiran Kulkarni and others carried out extensive studies on two lectins from winged beans which have the legume lectin fold and are dimeric. Another legume lectin studied in the lab, by Kiran Kulkarni, S. Thamotharan and others, was the recombinant form of *Erythrina corallodendron* lectin. Yet another legume lectin studied under the exclusive leadership of Suguna, in collaboration with Nadimpalli Siva Kumar of the University of Hyderabad, was that from *Dolichos lablab*. The student involved in the work was Kartika Shetty. Nagasuma Chandra (Suma for short), then a post-doctoral fellow, and Moses made significant contributions in elucidating the structural similarity and functional diversity in proteins containing the legume lectin fold. Moses was involved in comprehensively studying the variability in quaternary association of proteins with the legume lectin fold.

Structural studies on β-prism I fold lectins, have also been extensive. The work on jacalin has been particularly extensive. Artocarpin and banana lectin were also studied thoroughly. In addition to Sankaranarayanan and Sekar, those who worked on these lectins include J. Venkatesh Pratap, A.

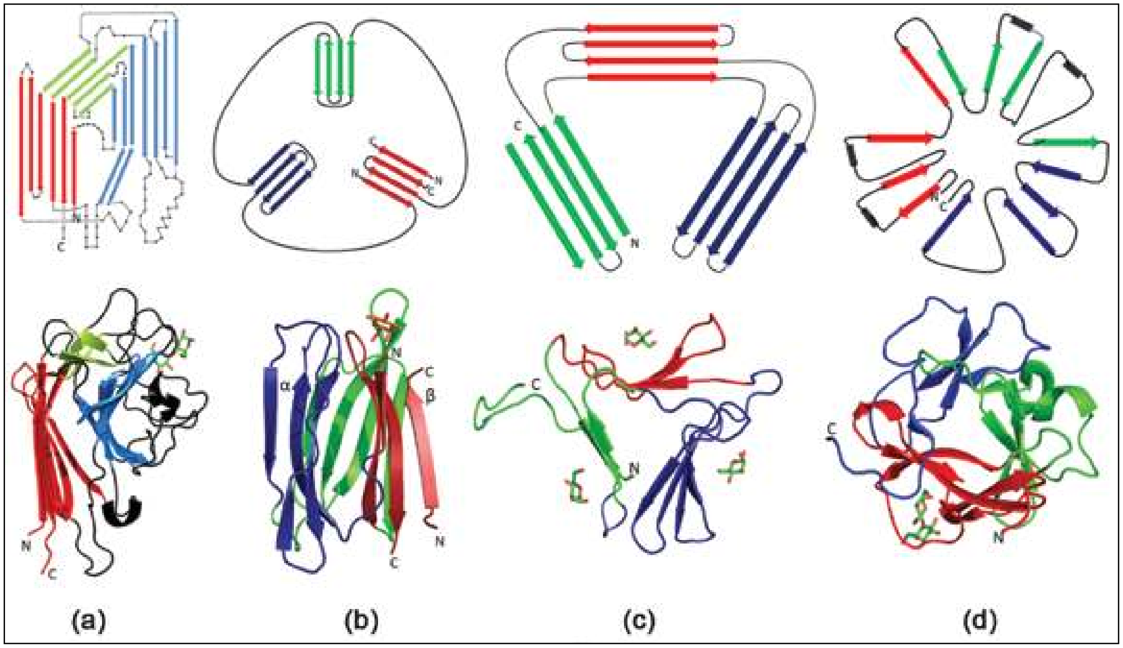


*Figure 3. Subunit structures of four families of plant lectins studied in the laboratory. The top panel illustrates the folds and the bottom panel shows the corresponding three-dimensional structures. Bound sugars are shown as sticks. (a) Legume lectin (Peanut lectin), (b) β-prism **I** (Jacalin), (c) β-prism **II** (Garlic lectin), (d) β-trefoil (one lectin domain of **SGSL**). reproduced from Curr. Sci.* **116**, *1490-1505, 2019.*

Arulanandam Jeyaprakash, Stephen Suresh, Desh Deepak Singh, Alok Sharma and K.V. Abhinav. Among them, Deepak came to the lab as a post-doctoral fellow after a long break from science. He got back to science through the work on banana lectin.

Among the β-prism II fold lectins, garlic lectin was a difficult protein to crystallize. The lectin crystallized once in the hands of Suma. She made full use of those crystals. Subsequently she was joined by Gosu Ramachandriah, a student. Another interesting β-prism II fold lectin investigated in the laboratory of Suguna was that from *Remusatia vivipara*. The main contribution in the structural work on the lectin, performed in collaboration with B.M. Swamy of the Karnataka University, came from Kartika.

Non-toxic homologues of type II Ribosome Inactivating Proteins (RIP) are of considerable interest in relation to their affinity towards some tumors and also from an evolutionary perspective. The first such protein studied by us was snakegourd seed lectin (SGSL) provided by M.J. Swamy of the University of Hyderabad. We also worked with him and a German group in the complete analysis of its sequence and structure. In addition, we worked on bittergourd seed lectin (BGSL) which is again a nontoxic type II RIP. The students involved in the effort were mainly Alok Sharma, Thyageshwar Chandran and N. Sivaji.

The names mentioned in the above narrative are primarily of students and post-docs who carried out the crystallography and related investigations. The young colleagues who provided biochemical support include the late Mohammed Islam Khan, M.J. Swamy, S.R. Patanjali, V. Anantharam, M.V. Krishna Sastry, S.K. Mahanta, K.D. Puri, Shreeta Acharya, Vivek Sharma, Mili Kapoor, Sandra Misquith, Kiran Bachhawat, C.P. Swaminathan, V. Bhanuprakash Reddy, Anita Patil, Dipti Gupta and Padmanabh Mishra.

Our plant lectin programme spanned about forty years from the time I met Surolia in 1978 to 2018 when our last paper on plant lectins was published in *Glycobiology*. The work has produced significant results covering different aspects, which have been published in about 70 scientific papers. In addition to information specific to individual lectins, many results of considerable general interest have emerged from the work. They pertain to protein folding, quaternary association, strategies for generating ligand specificity, molecular plasticity and hydration and evolutionary relationship among lectins. These results, although very significant and impactful, are perhaps too technical for a general reader.

A major impact of crystallography of plant lectins in our laboratory has been in training leaders of structural biology in India. Many of them cut their macromolecular crystallography teeth on plant lectins. A majority of doctoral students who worked on these proteins returned to India after post-doctoral stints abroad. Those who worked on plant lectins in our laboratory and are now occupying leadership positions in India include Dinakar Salunke (currently Director, International Centre for Genetic Engineering and Biotechnology, ICGEB, New Delhi), Shekhar Mande (Director General, CSIR), Rahul Banerjee (Saha Institute of Nuclear Physics, SINP, Kolkata), Ravishankar Ramachandran (Central Drug Research Institute, CDRI, Lucknow), R. Sankaranaryanan (Centre for Cellular and Molecular Biology, CCMB, Hyderabad), K. Sekar (IISc), Nagasuma Chandra (IISc), Gosu Ramachandriah (Jubilant Biosys, Bengaluru), Venkatesh Pratap (CDRI), M. Manoj (IIT Madras), Kiran Kulkarni (National Chemical Laboratory NCL, Pune), S. Thamotharan (Sastra University, Thanjavur), Desh Deepak Singh (Punjab University, Chandigarh) and Thyageshwar Chandran (National Institute of Technology, Warangal). We have had close interactions with the families of these former students and postdocs as well. We came to know Dinakar's wife Madhuri and daughter Kanchan well. Shekhar Mande and his wife Sharmila, also a scientist, have been almost our family members. We have visited the homes of most others mentioned above.

Towards microbial lectins

The general feeling is that most of the important structural features of plant lectins have already been elucidated. A significant component of this information available globally, has emanated from our laboratory. Therefore, it was time to move on to lectins from other sources. Starting from the turn of the century, we had established a vibrant programme on the structural biology of TB and other mycobacterial proteins (see later). Therefore, it was appropriate to start work on mycobacterial lectins. A genomic bioinformatic search carried out by K.V. Abhinav, with the help of Alok Sharma, led to the identification of 94 lectins from 20/30 mycobacterial species/strains. Dhabaleswar Patra and others cloned, expressed and purified two of them. Dhabaleswar also carried out detailed physico chemical studies of one of them and structure determination of one domain of the same protein. That provided a good start for the work on mycobacterial lectins. As a one-off effort, Suguna and her student Farha Khan worked on lectins from *Entamoeba histolytica* as well.

A domain of life which has so far remained unexplored in relation to lectins is archea. A thorough genomic search by Abhinav and Ebenezer Samuel, a postdoc, resulted in the identification of 46 lectins from 29 archeal species. Sivaji and Abhinav cloned, expressed and purified one of them. Sivaji has also solved the structure of this lectin. With the identification of lectins in archea and the detailed physico-chemical and structural studies on one of them, it has been established that lectins exist in all three domains of life, viz., eukaryotes, eubacteria and archea. Presumably, lectins evolved to the present form well before the three domains diverged.

The work on mycobacterial and archeal lectins is still in the early stages and its full potential is yet to be realized.

Hydration, plasticity and protein action

Life, as we understand it, is possible only in an aqueous environment. Biological macromolecules are truly water-logged entities. The structure and action of proteins are retained only when the protein molecules are hydrated. Even crystallography on proteins are carried out in conditions under which the molecules are hydrated. As mentioned earlier, protein crystals contain typically 50% water. As outlined earlier, protein crystals undergo reversible water-mediated transformations when the relative humidity around the crystals is systematically varied. Max Perutz had used variation in the crystal parameters of haemoblogin as a function of water content for a limited purpose, in 1950s. Protein crystallography was then at its infancy and the full implications of the observation were not realized. Our efforts established water-mediated transformations as widespread phenomena and we used them systematically to derive meaningful results.

Building on the exploratory results outlined earlier, we thoroughly pursued water-mediated transformations primarily in lysozyme, to start with. Detailed refinement of the low humidity form of tetragonal lysozyme was carried out by R. Kodandapani with the help of C.G. Suresh. The results were published in a paper in the *Journal of Biological Chemistry* in 1990. That was the major definitive structural paper pertaining to water-mediated transformations. The relevant work on lysozyme was put on a firm footing by Madhusudan. Kodandapani and Madhusudan obtained their Ph.D. degrees primarily working on the water-mediated transformations in lysozyme. The other students who obtained their doctorates mainly working on lysozyme were H.G. Nagendra and Bichitra K. Biswal. Notable contributions to the effort were made by post-doctoral fellows C. Sudarshana Kumar, N. Sukumar, N.T. Saraswathi and R. Sankaranaryanan (a diiferent Sankaranarayanan from the one who solved the structure of jacalin).

Protein molecules exhibit considerable plasticity. Different regions of the molecule have different levels of flexibility. Water-mediated transformations, among other things, turned out to be a tool for exploring this plasticity. Removal or addition of a few water molecules, which is what causes the transformation, is the gentlest way of treating a protein molecule. The changes brought about by such removal or addition, are likely to correspond to the intrinsic mobility of the molecules. Using other available structures of lysozyme and the structural information obtained from our study involving water-mediated transformations, we could delineate the relatively rigid and flexible regions of the protein molecule (Figure 4). A protein molecule is surrounded by hundreds of water molecules, constituting the hydration shell. Some of these water molecules are particularly important for the structural integrity of the protein molecule and its action. We refer to them as invariant water molecules (Figure 5). The structural information obtained from water-mediated transformations helped us to identify such invariant water molecules. Yet another interesting study pertaining to hydration shell had to do with the effect of stabilizing agents on it. In addition to their importance in fundamental studies, the stabilizing agents are extensively used as food preservatives.

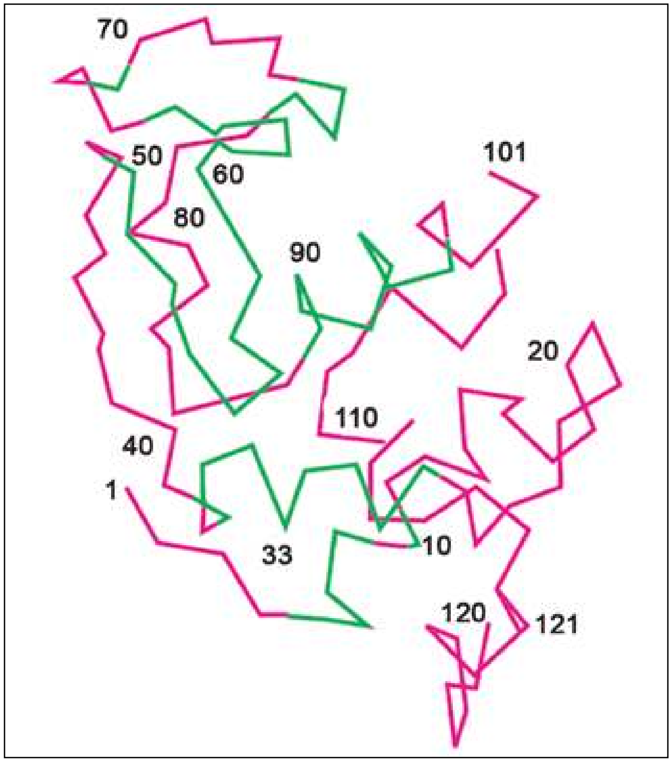


Figure 4. Comparatively rigid (green) and flexible (red) regions in lysozyme.

The most exciting result of the work is concerned with the relation among hydration, mobility and protein action. The molecules in a dry protein sample are immobile and inactive. It has been shown in the case of lysozyme that water of about 20% of the weight of the protein sample need to be added before mobility and action simultaneously set in. Through studies involving water-mediated transformations of lysozyme crystals, it could be shown that the changes in the molecular structure that occur during partial dehydration are similar to those that occur during enzyme action. As a one off case, Nagendra could also obtain a monoclinic lysozyme crystal with water content much less than 20%. This crystal form thus had an intact molecule without activity and hence permitted the identification of possible determinants of activity (Figure 6). It also turned out that often low humidity forms diffracted better than the native crystal. This observation has been made use of by many groups around the world to improve the resolution of structures.

In parallel, extensive studies on water-mediated transformations in the crystals of ribonucleaseA were carried out by K.V. Radha Kishan, Suma, C. Sadasivan and Sudarshanakumar, all post-doctoral fellows. The results were similar to those obtained from the exploration involving crystals of lysozyme. In yet another study, water-mediated transformations in β-lactoglobulin were examined. In the native structure, a particular loop has an open conformation. When the ligand binds, this loop closes over the ligand. In the low humidity form of the native protein, the open loop moves towards the closed position, again indicating that the movements associated with

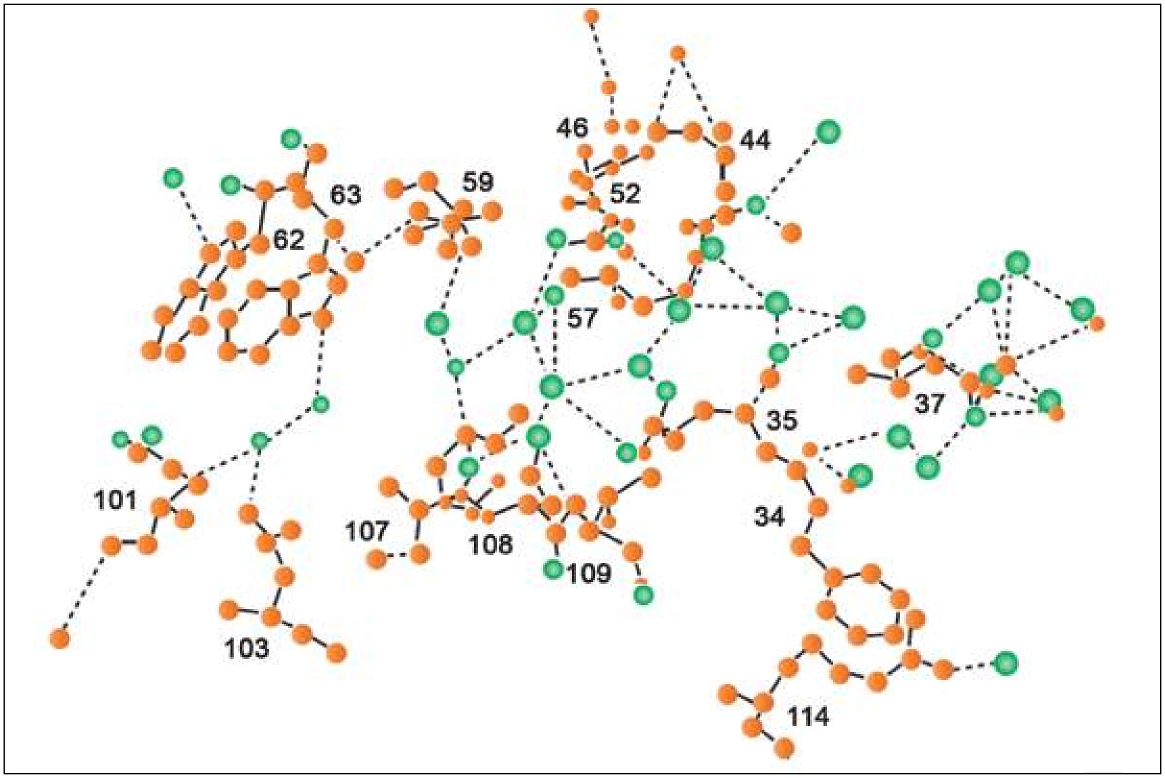


Figure 5. Water molecules (green balls) in the binding site of lysozyme. Large balls represent invariant water molecules.

partial dehydration tend to be similar to those that occur during protein action. This work was carried out by the visitor L. Vijayalakshmi with the help of Sankaranarayanan and R. Krishna, another post-doctoral fellow.

It was desirable to examine the effects of water-mediated transformations on the crystals of a complex protein. Haemoglobin was chosen for this purpose. The mechanism of action of haemoglobin is based on the equilibrium between a liganded relaxed state and an unliganded tense state. Through extensive studies carried out by Bichitra, Prem Singh Kaushal, another student, and Sankaranarayanan, we could characterize states intermediate between the tense and relaxed states. This again suggests that changes during partial dehydration mimic those that occur in the course of protein action.

I believe that the results we obtained primarily using water-mediated transformations are of fundamental importance. Among the students who obtained their doctorates working primarily on hydration, Nagendra is now a senior Professor at Sir M. Visvesvaraya Institute of Technology, Bengaluru, while Bichitra is a senior scientist at the National Institute of Immunology, New Delhi.

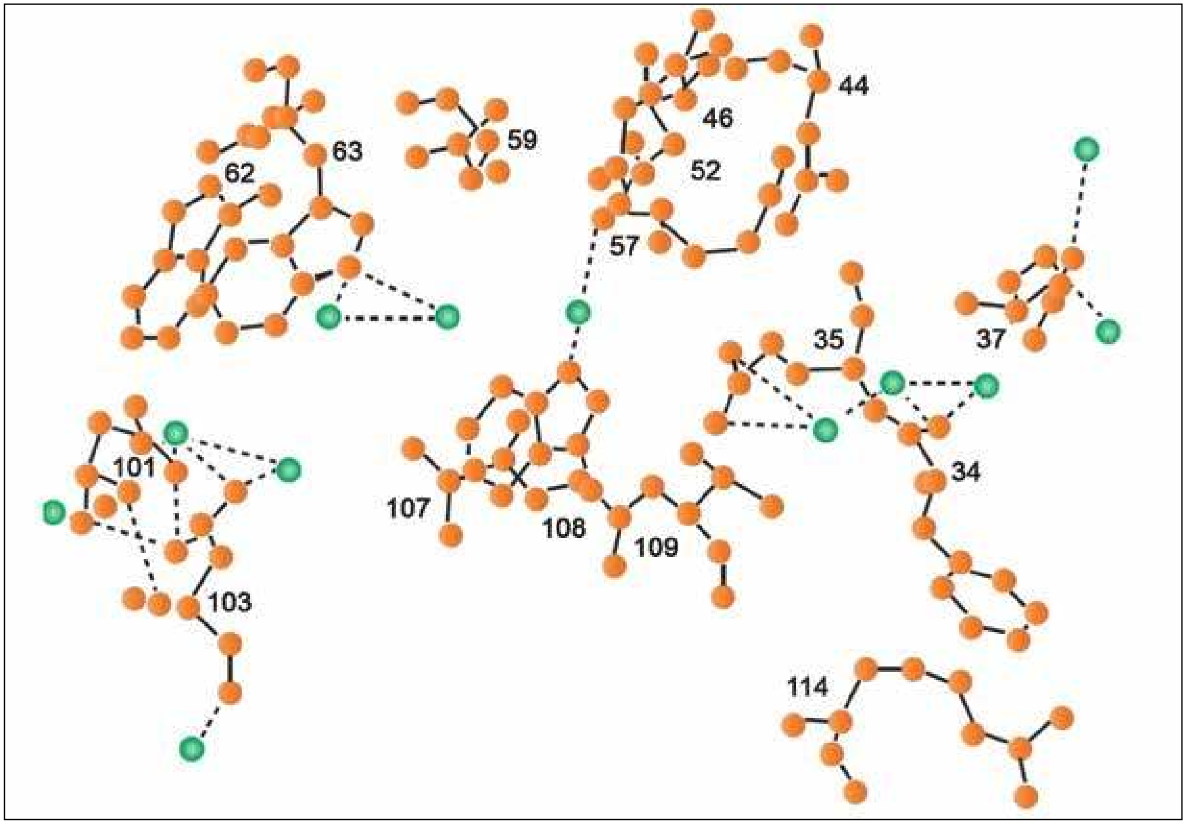


*Figure 6. Water molecules in the binding site of the very low solvent content form of lysozyme. Adapted from **PROTEINS: Structure, Function and genetics** **32** 229-240, 1998. This Figure may be compared with Figure 5.*

Sudarsana Kumar and Sadasivan work at the Mahatma Gandhi University, Kottayam and Kannur University, Kannur, respectively. We have been in touch with all of them. Radha Kishan moved to industry. The primary areas of work of Saraswathi, Suma and Krishna were in other programmes. Interestingly, more postdoctoral fellows than students were involved in the programme on water-mediated transformations. I entertained more postdoctoral fellows in my laboratory than many others do. Generally, I recruited them from less endowed institutions and turned them into scientists familiar with modern approaches and facilities. The programme on water-mediated transformations turned out to be a good platform for this purpose.

Consolidation and expansion of macro-molecular crystallography in India

In addition to the work on lectins and water-mediated transformations described earlier, a major effort at Bengaluru was on two plant viruses, sesbania mosaic virus (SMV) and physalis mottle virus (PhMV), by M.R.N. Murthy and H.S. Savithri. This major programme has had great impact on Indian structural biology. In the 1990s, work was initiated by M.A. Viswamitra, S. Ramakumar and others on xynalases. The second half of the 1990s also marked the beginning of crystallography studies on microbial proteins in Bengaluru. Structural work at BARC in the 1980s and the 1990s was primarily concerned with carbonic anhydrase, carried out by Kannan and his colleagues. Noteworthy efforts were made at BARC on the plant toxin gelonin as well. The long term programme on HIV protease by M.V. Hosur was also initiated before the dawn of the new century.

Macromolecular crystallography studies were initiated in a few more centres in the 1990s. One such major centre was at AIIMS, New Delhi, led by Tej Pal Singh and involving Punit Kaur, Sujatha Sharma and others. Over the years, the AIIMS group came to deal with a variety of important problems. One major area of their research has been concerned with proteins in animal, including human, secretions. The group led by Jiban Dattagupta at SINP, Kolkata, has made important contributions, particularly in relation to proteases and protease inhibitors. Another laboratory where substantial work on proteases has been carried out is the one led by Vasantha Pattabhi at the Madras University. Many other problems have been subsequently addressed at Chennai by N. Gautham, D. Velumurugan, M.N. Ponnuswamy, Ponnuraj Karthe, K. Gunasekaran etc. Work of Dinakar Salunke and colleagues on molecular mimicry which expanded to address major issues in immunology, started at the National Institute of Immunology (NII), New Delhi in the 1990s and continued at the Regional Centre for Biotechnology (RCB), Faridabad and ICGEB, New Delhi. The group of C. G. Suresh at NCL, which addressed a variety of problems, also started functioning during the same period.

S. Krishnaswamy initiated structural studies on membrane proteins at Madurai Kamaraj University, towards the end of the decade. The research teams which got established at the turn of the century and subsequently made considerable impact on macromolecular crystallography in India were those of Shekhar Mande, successively in Institute of Microbial Technology (IMTech), Chandigarh, Centre for DNA Fingerprinting and Diagnostics (CDFD), Hyderabad and National Centre for Cell Sciences (NCCS), Pune; Amit Sharma, ICGEB New Delhi; H.S. Subramanya, Central Drug Research Institute (CDRI), Lucknow; and R. Sankaranaryanan, CCMB, Hyderabad. The primary focus of all the groups, except the last one, has been on proteins from microbial pathogens. Sankaranarayanan worked in many areas, but his most notable contributions pertain to proteins involved in proof reading during the translational stage of protein synthesis. During the first decade of the century, macromolecular crystallography in India entered a stage of rapid expansion and many groups got established in different parts of the country. I have been engaged with most of them, but the extent of their activities have been too large to be meaningfully summarize here.

Structural biology of mycobacterial, mainly TB, proteins

Macromolecular crystallography in India had come of age by the turn of the century. Some of the problems addressed such as plant lectins and plant viruses at Bengaluru and mammalian secretions at AIIMS, had a distinctly Indian flavour. However, the time was then ripe to address problems which are still more directly relevant to India. One such problem is infectious diseases, a problem that India shares with other comparatively poor countries. Therefore, structural studies on proteins from microbial pathogens are of considerable relevance to the country. The availability of the genome sequences of some pathogens including *Mycobacterium tuberculosis* which is the causative agent of tuberculosis (TB), added a fillip to the efforts. In this scenario, along with few younger colleagues, I orchestrated, primarily through DBT and the office of the Principal Scientific Advisor (PSA) to the Government, the need for a national effort on the structural genomics of microbial pathogens. That formed a useful backdrop for subsequent structural work in the area.

Over the years, proteins from malaria parasite, *Salmonella typhimurium*, *Leishmania donovani*, *Entamoeba hystolytica* and a couple of viruses, have been studied in India using crystallography. However, the most extensive studies have been on those from *M. tuberculosis* and related mycobacteria. India has a long and distinguished tradition of mycobacterial research. Molecular biology approaches became important in such research during the last few decades of the previous century. Structural biology work on mycobacterial proteins commenced in India towards the end of the century. The first such effort was the homology modeling, a non-trivial exercise those days, carried out in 1996 by Suma in my laboratory, as part of a larger piece of work by K. Muniyappa and his colleagues. This was soon followed by the brilliant annotation of an important *M. tuberculosis* gene using bioinformatics approaches by N. Bachhawat and Shekhar Mande. The first crystal structure of a mycobacterial protein to be solved in India was that of *M. tuberculosis* RecA in our laboratory in 2000. This was then among a handful of TB proteins with known three dimensional structure. Around this time, a TB Structural Genomics Consortium, based in the US and supported by National Institutes of Health (NIH), but with worldwide participation was established. I was one of its early members. Some others from India also subsequently joined the Consortium which during its active existence was useful, particularly for networking among TB structural biologists. I particularly remember two very useful meetings of the Consortium at Santa Fe, USA in the early years of the century.

The most thoroughly studied mycobacterial protein in Bengaluru has been undoubtedly RecA (Figure 7), in collaboration with Muniyappa and Suma. Our strategy has been to study, to the extent possible, the protein from the nonpathogenic *M. smegmatis* along with that from *M. tuberculosis*. There have been instances where only the protein from *M. tuberculosis* could be crystallized, while in some other cases, only that from *M. smegmatis* could be crystallized. RecA from both the organisms, their mutants and complexes were thoroughly studied over a period spanning more than one and a half decades. The body of results obtained in Bengaluru on RecA has had considerable impact on global efforts pertaining to recombination and DNA repair. Recombination occurs in all forms of life and has a role in generating genotypic and phenotypic diversity. RecA is a critical enzyme involved in recombination in bacteria. In bacteria, the primary function of recombination is DNA repair. DNA continuously gets damaged for a variety of reasons. The damage should be promptly repaired for the viability of the organism. All organisms, including mycobacteria, possess a battery of enzymes to carry out the repair. RecA is an important such enzyme. As work on mycobacterial proteins progressed in the laboratory, structural biology of proteins

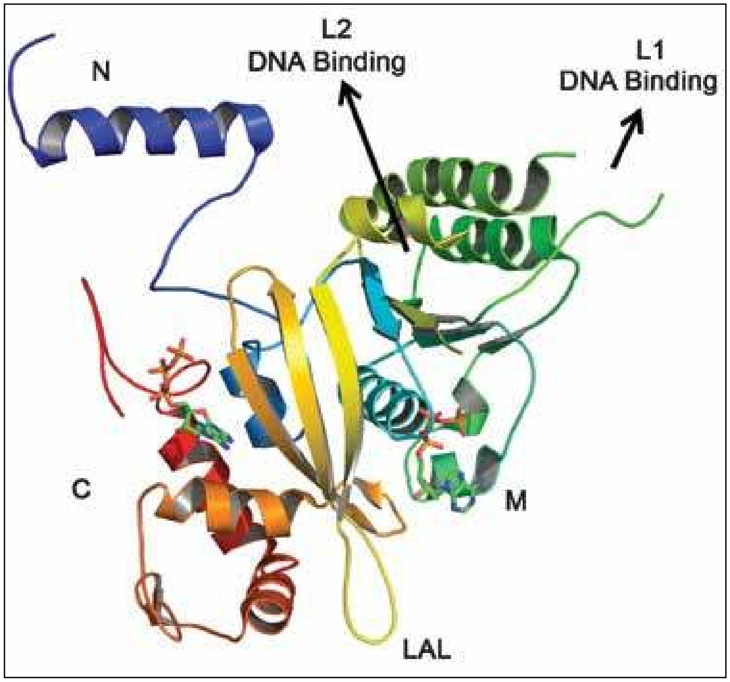


Figure 7. Tertiary structure of RecA. The bound nucleotides are indicated as sticks. Some functionally important regions of the molecule are indicated.

involved in preserving genomic integrity by repairing DNA or preventing damage to DNA, became the most important component of the effort.

RecA has been a difficult protein to crystallize. It took a couple of years to standardize crystallization conditions. Once conditions were standardized, RecA became an important work horse in our studies. The first definitive structural results on RecA was produced by Sunando Dutta. The others who obtained their doctorates working on RecA were J. Rajan Prabu and Anu V. Chandran. The post-doc R. Krishna also made important contributions to the effort. Rajan, along with Thamotharan and Suma, also carried out structural studies on RuvA, a protein specifically involved in recombination.

Single Stranded DNA Binding protein (SSB) (Figure 8) is involved in a variety of DNA transactions, including recombination and repair. Our efforts in collaboration with Umesh Varshney and Muniyappa on these proteins from ***M. tuberculosis***, ***M. smegmatis*** and ***M. leprae*** have been well received. In fact, we played a major role in systematising the structural features of SSB. The work was carried out by students Saikrishnan, Prem Singh and Amandeep Singh with the help of J. Jeyakanthan, a postdoc, and K. Sekar. Sri Kalaivani, a postdoc, is now involved in the SSB project. Another important DNA repair enzyme studied in our lab in collaboration with Umesh by students Saikrishnan, Prem Singh and Sheikh Mohammad Arif and postdocs Bidya Sagar and K. Geethanandan, was uracil DNA Glycosylase (UDG) (Figure 9). Here again, our efforts have been well recognized. In addition to repair enzymes, there are enzymes which prevent damage to DNA. MutT proteins are among them. Recently, again along with Umesh, Arif and Amandeep Singh have made important contributions to the structural biology of these enzymes. The student Prateek Raj and the postdoc Karthik Selvam are now involved in the work. Yet another protein involved in DNA repair studied by us is LexA, which triggers the so called SOS response. Students Anu and Anju Paul along with Sri Kalaivani, made important contributions to the effort. DNA molecules have to be protected and iron ions have to be properly sequestered under starvation conditions. DNA binding proteins under starvation (Dps) are involved in this process. Dipankar Chatterji has made important contributions in this area. In collaboration with him, the student Siddhartha Roy carried out extensive work on two Dps molecules, with the help of Sekar. The work was subsequently carried forward by Sunanda Williams and Anu.

Although our effort was primarily on proteins involved in repair and prevention of damage in DNA, we have also worked on proteins involved in other metabolic processes. We studied, in collaboration with Umesh, Ribosome Recycling Factor (RRF) and Peptidyl t-RNA Hydrolase (PtH), both of which play important roles in the translation stage of protein synthesis. The students involved in the work were primarily Saikrishnan and M. Selvaraj. The thorough work carried out in collaboration with Surolia by student Bhaskar Chetnani on Pantothenate Kinase (PanK) deserves

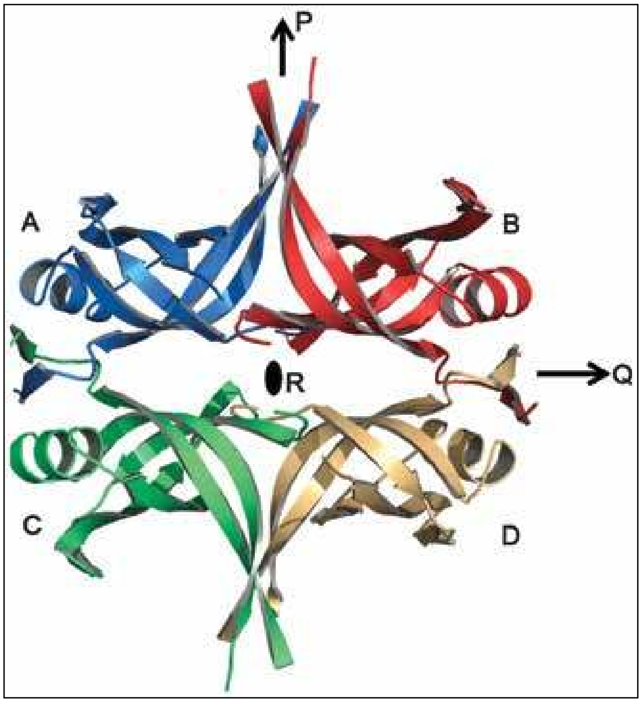


Figure 8. Structure of tetrameric mycobacterial SSB. Subunits are colored differently.

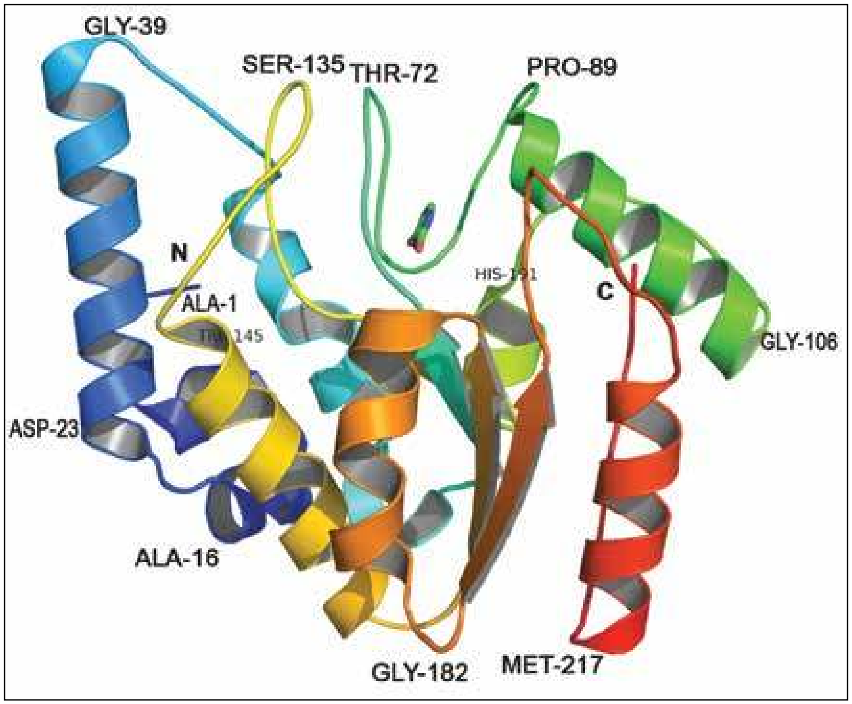


Figure 9. Tertiary structure of the DNA repair enzyme uracil DNA glycosylase (UDG). The bound uracil is shown as sticks.

special mention. Bhaskar was ably assisted by the postdoc Satyabrata Das. The work is being carried forward by Anju. We have been involved in structural work on a couple of other proteins as well in collaboration with Surolia.

The work on mycobacterial proteins has been made possible through extensive collaboration with Muniyappa, Umesh Varshney, Dipankar Chatterji and Surolia. Many of their students have contributed to the effort. One of them, Ganesh Nagaraju, is already a distinguished faculty member at the Institute. Sunanada has carried out biochemical as well as crystallography work during the later stages of the Dps project. Suma and Sekar, who had earlier contributed substantially to the lectin project as post-doctoral fellows, were deeply involved in the programme on mycobacterial proteins, as faculty members. The programme has involved the determination of about 175 independent crystal structures. The students and postdoctoral fellows who were with the programme are already in the process of occupying independent positions in the country. The students Sunando Datta, Saikrishnan, Siddhartha Roy and Prem Singh Kaushal are now at IISER, Bhopal; IISER, Pune; IICB, Kolkata and RCB, Faridabad, respectively. The postdoctoral fellows R. Krishnan and J. Jeyakanthan are faculty members at Pondicherry University and Alagappa University (Karaikudi), respectively. Thus the programme has served to mentor many leaders of Indian science, although not yet as much as the lectin programme has done. Incidentally, Saikrishnan is married to Gayathri, a former graduate student of M.R.N. Murthy and daughter of my old friend Rajasekharan Pillai. Saikrishnan and Gayathri are equally close to us. The same is the case with Siddhartha and his wife Chandrima who is an outstanding scientist working at SINP, Kolkata.

The synchrotron saga

My friend Guy Dodson used to say that two rings make all the difference to modern protein crystallography. The first is the circular DNA vector used in cloning. The second is the powerful synchrotron X-ray source which is in the form of a giant ring. Cloning and expression of proteins in large quantities constituted a problem in India even in the early years of the present century. During my campaign for structural genomics of microbial pathogens, we had a brain-storming meeting at DBT. In that meeting, paraphrasing Lenin, I recall mentioning that our first priority was expression, second priority was expression and third priority was expression. Those days are behind us. Proteins are now routinely cloned and expressed by students and lab assistants in almost all concerned laboratories in India. The same cannot be said about the second ring.

Although discussions on synchrotron facilities in India started in late 1970s, the first definitive meeting involving all the stake holders took place in 1984 at BARC. I, naturally, participated in the meeting. P.K Iyengar, S. Varadarajan and Rais Ahmed represented the Department of Atomic Energy (DAE), DST and UGC, respectively. It was decided that DAE would undertake to construct simultaneously a low-energy Indus-1, which is of limited use, and a high energy Indus-2 which is what most of us were concerned with. After a lapse of few years, work on the facilities began at the Centre for Advanced Technology (CAT), Indore, which was subsequently rechristened as Raja Ramanna Centre for Advanced Technology (RRCAT). The 450 MeV Indus-1 was commissioned in 1999.

Indus-2 did not appear to be anywhere near the horizon at that time. Macromolecular crystallographers in India and other potential users began to get restive about the inadequate progress of Indus-2. The bilateral arrangement made by DST for use of synchrotron facilities abroad were of some help, but did not solve the problem. In 2004, a meeting was organized at Hyderabad by Syed E. Hasnain, the then director of CDFD and Kota Harinarayana, the then Vice-Chancellor of Hyderabad University, with the help of Shekhar Mande, to discuss the issue. I was invited to chair the meeting. The meeting was attended by a cross section of scientists concerned with synchrotron facility.

The Hyderabad meeting recommended the setting up of a second high power synchrotron facility, in addition to expediting the work on Indus-2. R. Chidambaram, the then PSA, and Vinod Sahni, the then Director of CAT, were kept informed about the deliberations of the Hyderabad meeting. Some of us subsequently visited Indore and had discussions with the scientists there. That was the beginning of meaningful interactions between those involved in constructing the facility and a large section of the user community. Since then, I have visited Indore several times to encourage workers there and to sensitize them on the requirements of the user community.

On account of the vigorous campaign some of us mounted, synchrotron facility by then was a topic of national discussion. That was the time when the Eleventh Five Year Plan was being formulated. A major recommendation of the concerned Plan report was to lease/set up beamlines at synchrotrons abroad. Preparation of a project report for a new facility was also envisaged, in addition to strengthening the Indore facility. In pursuance of the first of these recommendations, I took the initiative, as the Chairman of the concerned committees, for beamlines at the European Synchrotron Radiation Facility (ESRF) in Grenoble, France and Elettra, Italy. The Grenoble project was and continues to be supported by DBT while the Elettra project came under the domain of DST. Dinakar Salunke, Tej Pal Singh and B. Gopal played important roles in the Grenoble project. The Elettra effort was initiated and implemented primarily by D.D. Sarma. Shekhar Mande and S.M. Sharma ably assisted him. Deepak Nair is now primarily responsible for the Grenoble effort. B. Gopal is currently deeply involved with Elettra. The entire macromolecular crystallography community has been involved one way or the other in these efforts. The assured availability of beamlines at ESRF and Elettra makes a real difference to macromolecular crystallography studies in India.

In consonance with the recommendation of the Plan report referred to earlier, P. Balaram, the then Director of IISc, proposed in 2009 the establishment of a synchrotron facility at the newly acquired land in Chitradurga. The proposal was discussed at the Scientific Advisory Committee of the Cabinet (SAC-C) in August 2009. By then, I had become a member of the SAC-C on account of my position as the President of INSA. Soon afterwards, R. Chidambaram, the PSA, constituted a Committee co-chaired by S.K. Sikka and myself, with a broad mandate on synchrotron facilities in India. The Committee considered a proposal submitted by D.D. Sarma, on behalf of IISc, for setting up a 3 GeV synchrotron at Chitradurga. The discussions on this proposal proceeded smoothly until a proposal for a 6 GeV machine came out of the blue. The new proposal was presented by Milan Sanyal, on behalf of SINP/DAE. The simultaneous presence of two proposals virtually killed the initiative for a new synchrotron facility in the country.

The Vijayan-Sikka committee, which was efficiently piloted by Neeraj Sinha of the Office of the PSA, was more effective in dealing with Indus-2 at Indore. By then, P.D. Gupta had taken over as the Director of RRCAT. We developed an instant rapport with Gupta, who has been very sensitive to the requirements and suggestions of the user community. Eventually, Indus-2 became operational, which was a development to rejoice in, even though Indus-2 is not a state-of-the-art facility. By the end of 2013, the Scientific Advisory Committee to the Prime Minister (SAC-PM) also emphasized the need for a state-of-the-art synchrotron facility in India. Subsequently, Kasturirangan, then a member of the Planning Commission, organized, with my help, a broad based meeting on a possible new synchrotron facility in the country. The meeting recommended that DAE and DST together should work on the new synchrotron facility. The general election ensued in 2014 and the whole set-up changed. For all practical purposes, the plan for a state-of-the-art facility had a quiet burial. I have been deeply involved in almost every discussion on synchrotron facility for a decade starting from 2004. I believe that we would have been well on the way to a new synchrotron facility, but for clashes involving king-sized individual and institutional egos. I do not know when and how the efforts can be revived. If and when it is done, developments in free-electron laser technology and cryo-electron microscopy also need to be taken into account. Despite the disappointment in relation to an Indian facility, our sustained campaign was not fruitless. Assured access to ESRF and Elettra and the commissioning of Indus-2 with the active involvement of the user community, were major achievements.

A dream come true

My main career objective on my return from Oxford as the first trained macromolecular crystallographer to return to India, was the initiation and development of an area which is central to modern biology. To start with, the odds against it were formidable. There were friends who doubted whether this can be done in India. However, an overwhelming majority of elders and colleagues encouraged me to go ahead. It took almost a decade for preliminary results in the area to emerge from the country. Then came the timely support from DST in the mid-1980s. I have already acknowledged the help of S. Varadarajan, N. Seshagiri and others in making this support possible. In the meantime, almost the entire modern biology community of India was also with us. Yet, it almost took another decade for really significant results to emanate from our laboratory.

I specifically recall an instance in the mid-1990s in relation to the development in the area in the country. Ayagari Rao arranged for me to make a presentation before SERC on the current state of macromolecular crystallography in India. P. Rama Rao, the then DST Secretary was in the chair. He often used to recall the statement of mine in the presentation that "macromolecular crystallography in India now is more than a gleam in the eye". After the presentation I was naturally anxious about the reaction of the members. The first one to react was P.N. Tandon who is well known to me as a no-nonsense person capable of calling a spade a spade. The first sentence in his comment was, "this is the kind of work the nation should be proud of". Tandon turned out to have much to do in my subsequent career. He has always been one of my steadfast well-wishers and benefactors.

The presentation and the discussion in SERC referred to above, epitomize the state of the subject in the country and the attitude of the scientific community towards it. More than a "gleam in the eye" is a correct description of the situation at that time. However, there was still a long way to go. I was well into the 50s and I was not sure that I had enough time to complete the task I had undertaken. However, thanks to the support of my elders and colleagues, my institution and my department, I could lead the effort for almost two more decades.

Macromolecular crystallography has now become an important and major component of modern biology in India. It is being pursued in nearly 40 institutions and about twice as many groups. To a substantial extent, the area radiated from our lab in Bengaluru. A majority of the groups is probably manned by those who trained in Bengaluru and their descendants. I have the satisfaction of watching my students, grand students and great grand students performing well in the area. Over the years, many scientists trained in other institutions, including distinguished ones abroad, joined the community, adding to its vibrancy. They effortlessly merged into the overall community activities, including those involving shared facilities and programmes. Macromolecular crystallography studies in the country encompass almost all areas of modern biology and we have also begun to address nationally relevant issues. On the whole, I have a sense of satisfaction when I observe the current activities in the area in the country, although I am conscious that we have to do still better and scale greater heights. The excellent performance of some of my younger colleagues allows me to look ahead with optimism.

11

BIOINFORMATICS AND COMPUTATIONAL BIOLOGY. A COMPLEMENTARY ENGAGEMENT

Bioinformatics and computational biology come naturally to crystallographers. In fact, one of the earliest important databanks to be established was the Protein Data Bank (PDB). That was in 1971 with the coordinates of only a handful of protein structures in the database. I was among the early users of PDB. When I visited England in the mid-1970s, I collected the available data in the PDB from Bob Diamond, on a couple of huge magnetic tapes. My student T.N. Bhat then analysed the data for the side chain conformation in protein molecules, with some help from V. Sasisekharan. We published our analysis in 1979 in a comparatively less known journal called *International Journal of Peptide and Protein Research* (IJPPR). That was probably my first formal foray into bioinformatics. It turned out that this paper is the most cited one with me as the senior author, in spite of the low impact factor of the journal in which it was published!

In much of my work, I use computational tools to complement results from X-ray crystallography. Therefore, in many of my papers, computational approaches appear along with X-ray crystallography results. In addition to bioinformatics, I have extensively used molecular mechanics and molecular dynamics, particularly for exploring variability in quaternary association and the relative importance of conformational selection and induced fit in ligand binding. I published a few papers dealing exclusively with computational biology, mainly along with Alok Sharma and Anu Chandran. The stand-alone bioinformatics papers that I published include those on the genomic search for mycobacterial and archeal lectins, with K.V. Abhinav as the first author.

Role in international efforts

I have already referred to my involvement in the development of bioinformatics activities in the Institute. Almost at the same time as I commenced this involvement, I found myself seriously engaged in discussions and decision making on bioinformatics at the international level too. This resulted from my participation in the activities of the International Union of Crystallography (IUCr) and the International Union of Pure and Applied Biophysics (IUPAB), both of which adhered to ICSU (see Box 1).

To a substantial extent, IUCr functions through various Commissions. I have been a member of three of them at different times. The relevant Commission in the present context is that of Biological Macromolecules. I have been a member of this Commission continuously for nine years starting from 1987. I also functioned as its Chairman during 1993-96. It was during the period when I was associated with the Commission that the deposition policies on crystallography data were firmed up. After wide internal discussions, the policy of IUCr on publications and deposition of data from crystallographic studies of biological macromolecules was enunciated by the Commission in 1989. As per this policy, among other things, deposition of atomic coordinates in the PDB prior to the publication of the relevant structure was sought to be mandatory. This policy was communicated to all relevant journals.

Another definitive development took place in 1995 when I was the Chairman of the Commission. In that year, we organized an International Seminar-cum-School on Macromolecular Crystallography data at Kolkata. The local arrangements for this magnificent meeting were made by Jiban Dattagupta and his colleagues including my former student Rahul Banerjee. I deliberately chose Kolkata as the venue, as macromolecular crystallography efforts were then emerging there under the leadership of Jiban. The meeting had wide national and international participation. On the basis of the deliberations of the meeting, Ted Baker, Tom Blundell, Eleanor Dodson, Guy Dodson, Gary

The International Council of Scientific Unions (ICSU) was established in 1931. The full name was changed in 1998 to the International Council for Science, although the acronym was retained. Academies or other corresponding bodies of about 100 countries adhere to ICSU. Close to 30 international scientific unions are also members of ICSU. IUCr and IUPAB are two such Unions. ICSU has recently undergone one more metamorphism but that is not germane to our discussion. Each union has National Committees adhering to it in several countries. ICSU is a multifaceted, non-governmental organization with enormous reach and enjoys considerable prestige. The constituent Unions are semi-autonomous and often play a decisive role in the development of the concerned area in the world. Many of them, like IUCr, publish their own journals and are endowed with well-oiled organizational structures and adequate funding.

Gilliland, Joel Sussman and I wrote a common letter to all the relevant journals. Based on sound arguments, we recommended that publication of macromolecular crystal structures should be accompanied by deposition of atomic parameters and also structure amplitudes. This letter was enthusiastically received by the community and the journals. Most relevant journals took steps to implement our recommendation. For example, in the same issue in which our letter was published, *Nature* announced their intention to implement our recommendations.

The IUPAB Council is assisted by a number of Task Forces. During part of my tenure in the Council, I was also a member of the IUPAB Task Force on Bioinformatics (1996-98). Perhaps I was the only scientist who has been simultaneously involved in the bioinformatics activities of IUCr as well as IUPAB. That was probably the reason why I was considered as joint representative of IUCr and IUPAB in an important ICSU initiative outlined below.

The Inter-Union Bioinformatics Group (IUBG) was established on the initiative of IUPAB in 1998 as an Inter-Union activity addressing issues concerning the availability and maintenance of and free access to biological and biophysical scientific data. The Group had representatives of IUPAB, IUCr, the International Union of Biochemistry and Molecular Biology (IUBMB), International Union of Pure and Applied Chemistry (IUPAC) and the Committee on Data for Science and Technology (CODATA). It was supported by ICSU and UNESCO. The Group had a 9-membered steering committee chaired by Jean Garnier with Herman J.C. Berendsen as Secretary. I was a member of the steering committee, representing IUPAB and IUCr. There were other members who represented two unions individually. The Group had a broad mandate encompassing all aspects of data generation, archiving, maintenance, accessibility etc.

The first meeting of the Group was held towards the end of 2000 at Whitehead Institute, Cambridge, Mass., USA, along with a very interesting scientific symposium. The meeting and symposium paralleled the release of the first draft of the human genome by Bill Clinton and Tony Blair in Washington. The symposium was extraordinarily illuminating to me. The next two meetings which I did not attend, were held in Italy and the U.K. The final meeting which I attended was held in 2002 at the ICSU headquarters in Paris. The report of the Group was finalized at this meeting in Paris. The statements and the recommendations in the report had, to a substantial extent, guided the handling of biological data by the global scientific community.

National efforts

The Department of Biotechnology (DBT) was formally established in 1986. As an act of great foresight the bioinformatics activities of the DBT, formally described as Biotechnology Information System (BITS), were started in 1987 under the active guidance of N. Seshagiri, one of the architects of IT revolution in the country. The Bioinformatics setup of DBT was led for a decade by J.R. Arora. His role was subsequently performed with equal distinction by T. Madhan Mohan. An early Bioinformatics Centre set up by DBT was at the Institute under the guidance of M.A. Viswamitra. I assumed this role after his retirement in 1993. Interactive graphics facilities are common place now. The situation was very different in the 1980s. Graphics operations were performed using massive stand-alone instruments. Such facilities were woefully unavailable in the country. The first interactive graphics facility was set up at the Institute on my initiative with the help of Seshagiri. Subsequently, I was involved in setting up graphics facilities in a few more centres in the country. That was probably my first foray into organized bioinformatics efforts in India.

Bioinformatics and computational biology in India were passing through a critical phase during the period when the bioinformatics activities were formally started by DBT. The initial momentum of the area in the country generated by GNR and his colleagues had begun to wane for a variety of reasons. In the meantime, the area became highly computer-intensive. As already indicated, severe restrictions on import imposed by USA and other countries came in the way of our acquiring state-of-the-art computers. Furthermore, major advances in the area began to be based on large macromolecular structural, and subsequently sequence, data. Synergy between experimental data and computational studies based on them, is fully realized only in an ambience involving the generation of such data. Structural data and subsequently sequence data, began to be produced in India on a significant scale only by the turn of the century. With the advances in the relevant technology, computer facilities also ceased to be a major problem. The role of BITS in making computers available and spreading computer literacy among biologists during this critical phase, was remarkable. All these factors put together led to an impressive resurgence of bioinformatics and computational biology in the country in the early years of the century. The role of BITS in this resurgence has indeed been very significant.

I have all along been part of the bioinformatics activities of the DBT and have been a member of the Bioinformatics Task Force of DBT continuously from 1993 to 2002. After a break, I assumed the Chairmanship of the Task Force in 2006 at the invitation of M.K. Bhan, the then Secretary of the DBT. I continued in that position till 2013. Even before I assumed the position, Bhan who succeeded Manju Sharma as Secretary, DBT in 2004, used to have discussions with me on the nature and the role of BITS. He rightly felt that there was adequate informatics but inadequate 'bio' in the setup. As an immediate alleviating step, he included a few experimentally oriented scientists in the Task Force.

I addressed the issues raised by Bhan and my own specific inclinations, after I assumed the Chairmanship of the Task Force. In some quarters, there were doubts even about the utility of BITS.

The BITS network encompassed well over a 100 centres distributed all over the country. I believed that the network still had a very important role to play. What was needed was not dismantling the system, but strengthening it through the infusion of new ideas and activities. That is precisely what I proceeded to do. It was a joint endeavor involving the Task Force and the administrative setup headed very competently by Madhan Mohan.

The primary role of the Bioinformatics setup till then was the management of the network. We brought in a substantial research component to the activities of the Task Force. We expanded the mandates of the Task Force to include computational biology and systems biology as well. The projects handled by the Task Force could now include an experimental component, as long as the big thrust of the effort was computational in nature. That helped in bringing about synergy between experimental and computational approaches.

The main strength of BITS was coherence of the network and the camaraderie among its constituents. The annual meetings of BITSnet Coordinators held in every early February, served to strengthen the coherence and camaraderie. The meetings were tightly scheduled, in an informal, may I even say homely, ambience. The first meeting I attended, along with Kalyani, was in Gangtok, Sikkim in February 2007. Gangtok in itself was a revelation. The Indian and Tibetan cultures co-existed amicably in the city and its environs. We were also surprised how seriously the authorities treated the meeting. In major scientific centres like IISc, IITs. TIFR etc. a meeting of this type would not even create a ripple. However, the coordinators' meeting in Gangtok was inaugurated by the Chief Minister of Sikkim. Two Ministers actively participated in the social events associated with the meeting. The morning after the inaugural session, I happened to put on the television in the hotel room. To my utter surprise, I could watch me giving the address at the inaugural function! The local TV had led the morning news with that on the inauguration of the coordinators' meeting! In any case, it was very satisfying that a small meeting of ours could generate so much excitement in the small community. Similar kind of excitement in the local community and keen interest of the authorities were visible when the meetings were subsequently held in Shillong in 2009 and Port Blair in 2010.

The 2008 coordinators' meeting was held in Mysore and that of 2011 in Pondicherry. The last coordinators' meeting with me as the Chairman of the Task Force was held in 2012 at Jammu and Katra. Again, Kalyani accompanied me. Much of the meeting was held under the benevolent gaze of Goddess Vaishno Devi! Kalyani made use of the occasion to visit the temple as well. As the helicopter services got disrupted on account of bad weather, she had to walk all the way from the temple to the plains. That, in a way, was testimony to her fitness!

I, and Kalyani whenever she accompanied me, enjoyed attending all the six coordinators' meetings. The meetings were scientifically very productive. Socially, they were in the nature of family get-togethers. As the meetings were held at different corners of India, they provided us with an opportunity to experience at first hand, the immense cultural diversity of India. These are among the occasions when my pride as an Indian was reinforced.

The area and those working in it were under some pressure during much of my association with the DBT Task Force on Bioinformatics (later, on Bioinformatics, Computational Biology and Systems Biology). Therefore, during the period, my emphasis was on defending the area and BITS. Preservation and strengthening the BITS network were then appropriate. I also tried to enhance the scientific content of the efforts of the Task Force. By the time I left the Task Force, the Bioinformatics/Computational Biology community no longer needed any particular external support. A robust new leadership had already emerged. In the meantime, the practice of Bioinformatics and Computational Biology had also undergone a qualitative change. A couple of decades ago, the help of specially trained persons was needed to carry out bioinformatics operations. This is no longer true. With increased awareness and availability of sophisticated software and a variety of databases, many experimentalists carry out their own bioinformatics operations. I am not entirely sure whether Bioinformatics would remain as a stand-alone sub-discipline. One is reminded of the changed status of Genetic Engineering. Not very long ago, it used to be treated as an independent sub-discipline. Genetic Engineering now is a routine tool in the hands of modern biologists. One wonders if the same thing would happen in relation to Bioinformatics/Computational Biology.

Open Source Drug Development (OSDD) was another effort with a substantial bioinformatics component, which I have been nominally associated with. OSDD was the brain child of Samir Brahmachari, the then DG CSIR. To an extent, the programme drew inspiration from the Open Source software movement. I was designated as one of the three mentors of the programme. That was probably a measure of Samir's consideration for me as someone deeply involved in the efforts on structural biology of TB proteins in the country. I was also the President of INSA for part of the duration of the programme. My real contributions to the work have been very little. However, I enjoyed participating in the discussions on the programme. I was also, and still am, excited about the concept of OSDD. Samir and his colleagues orchestrated the efforts of hundreds of scientists, young and old, in a very sophisticated manner, towards a common goal. I was very happy to have been part of this endeavor, although only nominally. The Open Source concept is applicable in other areas as well. I recall the presentation of V.S. Ramamurthy, at a meeting of the Presidents of the Academies of G8 +5 countries in Rome in 2009. I was then the President of INSA. Ramamurthy accompanied me to the meeting at my request. In that meeting, he advocated an Open Source approach in work on energy systems as well.

X-ray crystallography has been the main tool in my scientific researches. To a great extent, I have used bioinformatics/computational biology only to embellish the results obtained using crystallography. However, organizationally and on policy issues, I found myself at the centre stage of the area, both globally and nationally. That indeed was a rewarding experience.

12

CRYSTALLOGRAPHY AND BIOPHYSICS COMMUNITIES. ORGANIZATIONAL EFFORTS

X-ray crystallography and biophysics are at opposite poles in terms of the definition of the subjects. The origin of X-ray crystallography can be traced to the single event of the discovery of X-ray diffraction in 1912 by Laue. The subject then was developed in the early days by the Braggs. The subject essentially radiated from these two specific sources. Therefore, crystallographers as a community tend to be coherent. The technique itself clearly defines the boundary of the subject. The definition of biophysics is extremely hazy. A definitive origin of the subject cannot be assigned. The subject cuts across different levels of biological organization. Part of biophysics is closely aligned with physiology. Another part, on the opposite end of the spectrum, aligns with biochemistry and molecular biology. Fortunately, biological macromolecular crystallography and bioinformatics are claimed to be part of their subject by crystallographers as well as biophysicists. Therefore, I found myself engaged with both the communities, at the national as well as the international levels.

National Seminars on Crystallography, National Committee for IUCr, Indian Crystallographic Association

As indicated earlier, the first organized national effort involving crystallographers was perhaps the initiation of crystallography seminars in Chennai in 1964 by GNR. During the next few years, the seminar was held annually in Chennai. I attended the seminars each year until I left for Oxford

Dorothy in the Crystallography Congress in Beijing in 1993.
Behind her are (R to L) : Eleanor Dodson, Vijayan, Guy Dodson

Receiving the Ewald Prize on behalf of G.N. Ramachandran at the Glasgow Crystallography Congress in 1999.
(L to R): Vijayan, R. Chidambaram, Ted Baker

At the inaugural function of the Biophysics Congress in New Delhi in 1999.
(L to R): Vijayan, Manju Sharma, David Parry, Goverdhan Mehta.

(L to R): Ada Yonath, N.R. Jagannathan, Vijayan, R. Chidambaram during the Asian Biophysics meeting in New Delhi in 2011.

in 1968. Each year, we used to look forward to the seminar. In 1969, INSA became the adhering body of ICSU. The Academy in that year set up a National Committee of IUCr, with GNR as its first Chairman for three years. Since then, the National Seminars on Crystallography (NSC) became the responsibility of the National Committee. The NSC meetings began to be held at different centres of India. The first meeting of NSC held after the National Committee assumed its responsibility was designated as the first National Seminar on Crystallography.

During the first two decades of its existence, the National Committee has been chaired successively by GNR, A.R. Verma, S. Ramaseshan, N.N. Saha, R. Chidambaram and M.A. Viswamitra, all veterans of Indian crystallography. They also represented the different strands of crystallography activities in the country. From late 1980s, the mantle of Chairmanship fell on colleagues of my generation. The baton has now been passed on to the next generation. I was a member of the National Committee during 1985-88. My last formal association with this body was when I chaired the combined National Committee for IUCr and IUPAB during 2004-2008.

When Kalyani and I visited her parents in Chennai in early 1971, a NSC was in progress in the University. We attended some sessions informally. The first NSC meeting which Kalyani and I attended formally was at BARC, Mumbai in early 1972. The organizers led by V.M. Padmanaban and R. Chidambaram honored me by inviting me to give the main keynote address on the structure of insulin. By then, A.R. Verma had taken over as the Chairman of the National Committee. I recall his sitting in the front row and listening to all the lectures.

I have attended most of the subsequent NSCs. NSC turned out to be the most important annual event for Indian crystallographers. They have been held at different parts of India. Their role in engendering coherence in the Indian crystallography community has been invaluable. All the same, there was some disappointment that India did not have a national crystallography association. Veterans like GNR, A.R. Verma and Ramaseshan made attempts to form an Association, but did not succeed. I undertook this task in 2000. By then, I had developed easy rapport with crystallographers of all shades. As is my wont, I conducted elaborate discussions with almost all crystallographers of the country. All were very supportive. Eventually, a broad based Indian Crystallography Association (ICA) was registered in Bengaluru in 2001 with myself as the Founder President and Krishan Lal and S.K. Sikka as Vice-Presidents. This happened on the eve of the Asian Crystallography Association (AsCA) meeting in Bengaluru in November, 2001. This was the first major broad-based international crystallography meeting to be held in India. Part of the savings resulting from the conduct of the meeting was transferred to ICA, which enabled the Association to start its functioning with a reasonable corpus. From that time onwards, NSCs have been organized jointly by the INSA National Committee for IUCr and ICA.

Those who followed me as Presidents of ICA were Krishan Lal, Jiban Dutta Gupta, T.P. Singh, Dhananjay Pandey, M.R.N. Murthy and Punit Kaur. I gratefully recall the services rendered by N.C. Shivaprakash and K. Sekar in establishing and running ICA. My successors as Chairmen of the National Committee were Pinak Chakrabarti, Dinakar Salunke, Shekhar Mande and B. Gopal. I had interactions with Gautam Desiraju, who scaled great heights in IUCr. I continued to attend NSCs whenever I could. I particularly remember the 2004 NSC organized by C.G. Suresh at Pune, to which Kalyani accompanied me. The participants included Guy and Eleanor Dodson and a few other friends from abroad. It is in that meeting I launched the campaign for synchrotron facility. The last time I gave a major talk in a NSC was in 2013 when Tej Pal was the President of ICA. Kalyani accompanied me to that meeting. Both of us briefly participated in the NSC at Pune in 2016 organized by Shekhar Mande and his colleagues. That was the meeting at which my colleagues initiated the Vijayan Lecture series. We could be briefly present during the Vijayan Lecture at the NSC held in NIMHANS, Bengaluru in 2018, with B. Padmanaban (Tej Pal's former student and therefore my grand student!) as the main organizer.

IUCr: Congresses, activities, AsCA, exposure to new science, colleagues and places

I have also been involved with the activities of IUCr. IUCr conducts crystallography Congresses and General Assemblies every three years. The first crystallography Congress that I attended was the one at Amsterdam in 1975. Dorothy Hodgkin was then the President of the Union. The Amsterdam Congress left a deep impression on me. I recall running into Weissenberg at the Congress venue. I asked him whether he was the same Weissenberg who invented the Weissenberg camera which we then used routinely for data collection. I was thrilled when he said he was. I vividly recall the address of P.P. Ewald at the Congress. Another lecture that impressed me greatly was that of W.A. Wooster on his experiences as a crystallographer. J.D. Bernal was a towering personality and used to be referred to as "SAGE", in view of his vast knowledge. Wooster said that some of his colleagues wanted to ask Bernal a question which he would not be able to answer. They sought his views on Mexican architecture, as they were sure that Bernal would know nothing about that subject. Bernal shot back "do you want to know about the pre-revolution Mexican architecture or the post-revolution Mexican architecture?". I also recall Wooster describing a colleague in Cambridge as someone who would have been perfectly spherical, had he been a little taller! The Amsterdam Congress was my first introduction to the vastness and vibrance of crystallography. Naturally, I remember the details of the Amsterdam Congress more than those of the many crystallography Congresses I attended since then.

Dorothy was extremely busy during the Congress as she was then the President of the Union. After the Congress, she and Thomas Hodgkin, who accompanied her to Amsterdam, took me out for dinner. On the way to the restaurant, we noticed "Mujibur Rehman" prominently printed in a newspaper. The story was, of course, in Dutch. On enquiry, we were told that Mujibur Rehman has been assassinated. We were, like the rest of the world, shocked. Before returning to India, I spent a couple of weeks in England visiting friends.

The next major crystallography meeting I participated in was the International Winter School of Crystallography Computing, organized by the IUCr Commission on Crystallography Computing, in Bengaluru during January, 1980. The main local organizers of the meeting were Ramaseshan and Venkatesan. I was the Secretary of the Local Organizing Committee. Although much smaller in scope and participation compared to a Crystallography Congress, the meeting left a deep impression on me as it was the first intense meeting of that type I attended. In later years, I have had many opportunities for participating in such meetings.

The second Crystallography Congress I attended was in Ottawa in 1981. On the way to the Congress, I stopped in England for a couple of weeks to meet friends. In Ottawa, I stayed with our old friend Katiyar, his wife Sudha and their children. The scientific programme of the Congress was again very impressive. I was then mainly involved in the crystallography of small molecules. Small molecule crystallographers used to feel that they were not receiving the recognition they deserved, on account of the prominence of macromolecular crystallography. The sentiment was particularly orchestrated by Bill Duax who involved me also in the campaign for establishing an IUCr Commission on small molecules. Such a commission was established in the 1984 Crystallography Congress and General Assembly at Hamburg, which I did not attend. However, I was elected as a member of the Commission.

A major effort of the Commission on small molecules was the organization of an International Symposium in Beijing in 1986. China was just opening up and the symposium assumed considerable importance. Many leading crystallographers like Dorothy Hodgkin, Bill Lipscombe, Olga Kennard, David Harker and M.M. Woolfson participated in the meeting. Another participant whom I remember was Ada Yonath. Ada was then in the early stages of her journey towards the structure solution of ribosome. Ribosome is hardly a small molecule. Describing it as a small molecule would be like calling an elephant a microorganism! However the lure of China was such that even ribosome could find place in the programme of a symposium on small molecules.

I was then a comparatively junior scientist, but as a member of the Commission, I found myself located at the High Table, literally and figuratively.

In 1986, I was in England on an Exchange Programme for a couple of weeks, before my trip to China. The contrast between the two visits was striking. In England, I was traversing familiar territory. The visit to China was a voyage of discovery. As the capital of an ancient nation, Beijing had much to offer. In that ancient city, construction was evident everywhere. The roads were full of bicycles. Bicycle was the most common mode of transport. My friend Liang Dong Cai was then the Director of the Institute of Biophysics in Beijing. I recall a colleague of his telling that even Dong Cai came to the Institute on a bicycle. After the symposium, I spent a few more days in Beijing as a guest of the Institute of Biophysics. Another guest of the Institute at that time was Yu. T. Struchkov, a distinguished senior crystallographer from Moscow. He was the co-supervisor of Dong Cai when the latter did his Ph.D. in the Soviet Union. Struchkov and I were provided with a chauffeur driven limousine for our movements, in contrast to the bicycles on which most others travelled! Yet another contrast was between Sleeping Buddha, the hotel in which I stayed during the symposium, and the Friendship hotel where I was housed after the symposium, when I was the guest of Dong Cai. The former was a monastery converted into a hotel and was characterized by extreme simplicity. We could even see devotees coming to worship Sleeping Buddha. The Friendship hotel, built earlier by the Soviets, was a grand, modern structure.

During the symposium and as a guest of the Institute of Biophysics, I had the opportunity to see a great deal of Beijing. The visit to the Great Wall was naturally memorable. The country side on the way to the Wall was impressive. I was particularly fascinated to see peasants ploughing their land using horses.

Dong Cai took good care of Dorothy, Struchkov, myself and others, including by taking us to a Peking Duck restaurant. Another memorable event was a banquet at the Great Hall of the People at the Tiananmen Square. In relation to the Great Hall, I cannot resist narrating an incident which was related to Dorothy by Bernal. Bernal was a guest when the tenth anniversary of the Chinese Revolution was celebrated in 1959. The main function was at the Great Hall. That was the time when the Communist Block was still reasonably monolithic. All the communist leaders like Khrushchev and Ho Chi Minh were present on that occasion. All of them and many Chinese leaders made suitable speeches. One man was conspicuous by his silence. That was Mao Zedong. Traditionally, Chinese emperors never spoke on such occasions!

The Crystallography Congress next year (1987) was at Perth, Western Australia. The main organizer of the Congress was Ted Maslen, a former student of Dorothy. Happily, the venue of the Congress was the University. Many of us were housed in students' dormitories. An important event that took place in the General Assembly at Perth was the founding of the Asian Crystallographic Association (AsCA). Sydney Hall was the moving spirit behind this initiative. I had much to do with AsCA and Syd in later years. Our work on proteins was beginning to yield results and I was elected to the Commission on Biological Macromolecules, of which I was the Chairman during 1993-96. Interestingly, I was simultaneously a member of the Commission on small molecules and that on Biological Macromolecules during 1987-1990! Much of my work in 1987 was still on small molecules and I was the Organizing Chairman of a symposium on "Molecular Complexes and Inclusion Compounds" at the Perth Congress.

The next Crystallography Congress I attended was at Beijing in 1993. Just before the Congress, I was appointed as a Co-editor of *Acta Crystallographica*. I was the first Acta Co-editor from a third world country. That was not the primary reason for my appointment. At that time, Acta had a composite editorial board which dealt with all aspects of crystallography. I was among the few crystallographers who worked on small as well as large molecules. That was part of the reason for my inclusion in the editorial board. I did indeed deal with small as well as large molecules during my tenure as Co-editor which lasted till 2002. When I joined the Board Charles Bugg was the Chief Editor, a position which was later occupied by John Helliwell. The major editorial meetings, which took place close to the time and venue of Congresses, were interesting affairs. The Board was necessarily made up of colleagues from different countries and they spoke English with different accents and varying levels of mastery. Yet, the discussions were thorough and useful. The Editorial Board was and continues to be ably supported by the super-efficient staff at the IUCr headquarters at Chester, England. Naturally, my editorial association with IUCr journals started at the Beijing Congress.

Among other things, I organized a symposium on "Molecular Structure and Biological Activity" at the Beijing Congress. I was also an invited speaker in the symposium on "Protein-saccharide Interaction". It was in that symposium that I first presented our novel results on peanut lectin. As always, the scientific programme of the Congress was stimulating and the proceedings of the General Assembly were interesting. I was also stuck by the transformation that Beijing had undergone since my last visit in 1986. Bicycles had almost disappeared from the roads. They were replaced by motor vehicles. No horse drawn ploughs were visible on the way to the Great Wall. The Friendship Stores, where traditional Chinese artifacts were in abundance, were now conspicuous by their rarity. On the other hand, malls and modern shopping centres abounded. Beijing had become a modern city with all its virtues and vices.

I have already referred to the vibrant though silent presence of Dorothy in the Congress. I became the Chairman of the Commission on Biological Macromolecules at the Beijing Congress. A major concern of the Commission during my tenure was in relation to the deposition of atomic coordinates and the structure factors in the PDB. Our efforts on this issue have already been outlined.

Till the Beijing Congress, I used to attend only every other Crystallography Congress. My deep involvement in IUCr affairs led to my participation in every Congress during the next several years. The Beijing Congress was followed by one at Seattle in 1996. The last and the only time I visited USA was in 1969. After returning to India, my major pre-occupation was the development of macromolecular crystallography in the country. I somehow felt that I should next visit USA only after the foundations of the area have been laid in the country and earned recognition for ourselves on the basis of work done in India. By 1996, I was the Chairman of the Commission on Biological Macromolecules and a Co-editor of *Acta Crystallographica* and consequently a member of the Commission on journals. I had been invited to organize and chair a symposium on "Protein-Carbohydrate Structure" at the Seattle Congress. Furthermore, I was invited to present our results on jacalin in the symposium on "Hot Structures". Therefore, it was with a happy frame of mind that I decided to participate in the Seattle Congress, 27 years after my first visit to USA.

Obtaining a US visa is most often an uncertain exercise. This was particularly so during the time I was planning to go to Seattle. My travel agent was not prepared to undertake the responsibility of securing a visa for me. I was told that a personal appearance at the US Consulate at Chennai was essential. The usual procedure was to queue up for hours for an interview with unpredictable results. I took a chance and wrote a letter to the Consulate. In the letter, I explained my role in the Seattle Congress and sought their advice as to how I should go about to secure a US visa. I was whistling in the dark. Surprise of surprises, I received a prompt reply asking me to send my passport and a completed application form to the Consulate, which I did. Within a few days, I got my passport back with the US visa stamped! Since then, I have visited US a few times. Every time I could obtain the visa without personal appearance. At some point of time, I was given a ten year visa, which made things easier. Mine is an unusual experience for which I still do not have an explanation.

The Seattle Congress was a grand affair. It was at Seattle that my friend Ted Baker was elected as President of IUCr. I became a member of the IUCr Sub-committee on the Union Calendar. It is an important Committee which recommends on the sponsorship by and financial support from IUCr for various events and meetings. I served on the Sub-committee for three terms till 2005. As I have mentioned earlier, I stayed with my former student Stephen Suresh in Seattle. He was then working in the laboratory of my friend Wim Hol. I visited the lab. Wim was also a speaker in the symposium I organized in the Congress. Many of our former students in the US participated in the Congress. It was wonderful interacting with them.

The 1999 Congress at Glasgow was very special as I gave the Ewald lecture in it on behalf of GNR. The participation in the Congress was preceded by visits to different laboratories in England, along with Kalyani. I was enabled to do so by the award of a Nehru Birth Centenary Visiting Fellowship by INSA. Our programme in England was taken care of by the Royal Society. The concerned officer in the Royal Society was surprised that she had to arrange hotel accommodation for us only in London. In most other places, we stayed with friends. Those whom we visited included Louise Johnson in Oxford, Ravi Acharya in Bath, Tom Blundell in Cambridge and, finally, Guy and Eleanor Dodson in York. After the York visit, Kalyani returned to London and proceeded to India, after staying a day with the Menons at Wembley. I went on to Manchester for a two day meeting of the IUCr Commission on Journals. The publication activity of IUCr had expanded so much that it was not feasible for the Editorial Board members to meet on the sidelines of the Congress.

Participation in the Glasgow Congress was again a rewarding experience. The decision on the 2001 AsCA meeting was taken in a meeting of the Executive Committee of AsCA held during the Congress. I made a bid for Bengaluru. There was a bid for Hong Kong as well. The Executive Committee voted in favour of the Indian bid. In addition to participating in the scientific and related programmes, I found time to go around the city. From Victorian novels, I had the impression of Glasgow as a smoke-filled city. Modern Glasgow is a very clean and pleasant city. I was also pleasantly surprised at the level of Indian influence on Glasgow. During the Congress, I stayed in a student dormitory and ate in the mess. Among the items on offer was vegetable kurma! Glasgow also has a vibrant Sikh community. Many Indian participants of the Congress often ate in the Langar associated with a Gurudwara.

On my return from Glasgow, I along with Murthy, Suguna and other colleagues got busy with preparation for the AsCA meeting in Bengaluru. We made sure that the entire Indian crystallography community got involved in the organization of the event. In fact, I wanted to use the event for enhancing the coherence of the crystallography community in the country. As mentioned earlier, ICA was established on the eve of the AsCA meeting which was held during 18 - 21 November, 2001. In addition to putting together a vibrant scientific programme, we also utilized the occasion to honour two veteran Indian crystallographers who were still with us then. They were S. Ramaseshan and A.R. Varma. GNR had passed away in early 2001. I had turned 60 in October, 2001. Murthy, Suguna and others organized a major international symposium in my honour soon after the AsCA meeting. The meeting was very well attended. I was overwhelmed by the consideration shown to me by my friends and colleagues in India and abroad. For instance, Mike James, a former student of Dorothy and who introduced macromolecular crystallography in Canada, came all the way from Alberta for four days to felicitate me. Another participant in the symposium was Ada Yonath who scaled Nobel heights later on. Most of my old Oxford friends were in attendance. The symposium was also an occasion for my former students, colleagues and friends from India and abroad to get together.

I was a member of the Programme Committee for the 2002 Geneva Crystallography Congress. I recall working closely with Louise Johnson in organizing the components of the programme concerned with biomolecular structures. The Congress was preceded by a two day meeting of the Editorial Board of IUCr journals (Commission on Journals) at Bottstein. The picturesque location was enchanting. The subsequent Congress at Geneva was, as usual, scientifically and socially very rewarding. Geneva is a historical city very close to the French border. I enjoyed the stay in the city.

The next major meeting connected with IUCr that I attended was the AsCA meeting at Hong Kong in 2004 (AsCA'04). By then, I had been deeply involved in the activities of AsCA and I had to attend the meeting in spite of a major embarrassment. The dates of the Hong Kong meeting directly clashed with the dates of the function for conferring the Padma awards by the President of India. I had received the Padma Shri Award that year. The President of India then was Abdul Kalam who knew me. I was aware that he had expressed his pleasure at the prospect of conferring Padma awards that year on a few scientists including myself. Therefore, it was particularly awkward not to be present in the investiture ceremony. However, I could in no way have skipped the Hong Kong meeting where I was slated to assume the Presidentship of AsCA, which I did. During the next three years, I served AsCA as well as I could with special help from Syd Hall and Mitchell Guss, who succeeded me as the President of AsCA.

My participation in the 2005 Crystallography Congress was part of a somewhat extended, pleasant stay at Florence, Italy. The Congress took place during August 23-31. The 18th International Symposium on Glycoconjugates (GLYCO-18) was scheduled to take place in the city during September 4-9. I had an invitation to give a major lecture at the symposium. At that time, Surolia was the President of the International Glycoconjugate Organisation, under whose auspices the symposium was taking place. That was an added reason for me to participate in the symposium at least for a couple of days. Kalyani joined me at the conclusion of the Congress and we returned together to India after attending part of GLYCO-18. The Crystallography Congress was, of course, very exciting scientifically and socially. I also enjoyed my participation in GLYCO-18.

More than the two important meetings, it is Florence itself that first comes to mind, when I think about that particular trip abroad. Florence is filled with Renaissance glory. Stay in Florence was an experience in itself. That experience had added pleasure as Kalyani also joined me. The few days in between the two meetings gave ample time to explore the city. We also found time to visit Pisa of the leaning tower fame. When in Florence, we got the impression that we were esconced in a living museum. We also enjoyed the Italian cuisine in small, roadside restaurants. Kalyani was fascinated with the fare that she picked and brought back the illustrated menu card of one such restaurant, as a souvenir!

The 2005 Crystallography Congress was the last one I attended. Partly on account of my national preoccupations and subsequent ill-health, I could not attend any of the later Congresses. Thus the 2005 Congress marked the end of my 30 years long intense, formal involvement with IUCr. I also continued to be deeply associated with AsCA for a couple of more years. I attended AsCA'06 at Tsukuba, Japan and AsCA'07 in Taipei, Taiwan, as its President. In the meantime, we had started the campaign for bringing Crystallography Congress to India in 2014 or 2017. I played a leading role in this campaign on behalf of INSA and as the President of AsCA. In the initial stages, Australia was a contender for hosting the Congress. I could persuade Australian colleagues to withdraw from contention and support the Indian bid. Thus, our bid in effect turned out to be an Asian proposal. That obviously helped.

After a long gap, out of the blue, I received an invitation to give a plenary lecture in the December 2015 meeting of AsCA (AsCA'15) in Kolkata. I understand that the proposal for this invitation emanated from the Asian crystallography community, and not just from the Indian colleagues. I accepted the invitation with pleasure, even though I was substantially immobile. Kalyani and I attended the meeting. It was wonderful meeting so many of my old friends. At times, I forgot my disability in their company. I deeply appreciated their kind gesture in inviting me to give a plenary talk in the meeting of the Association whose President I was years ago. I was also overwhelmed by the meticulous care and affection with which my former students Rahul Banerjee of SINP and Siddhartha Roy of IICB looked after us. The participation in AsCA'15 was an appropriate way for me to sign off from the IUCr related activities.

Indian Biophysical Society, National Committee for IUPAB and promotion of coherence in the Indian biophysics community

Acharya Jagadish Chandra Bose is considered to be the first Indian biophysicist. His towering achievements are well known. Even after his passing away, Kolkata continued to be a major centre of biophysics in the country. In the 1940s and the 1950s, the leadership of the efforts rested with N.N. Das Gupta. S.N. Chatterjee, R.K. Poddar and S. B. Bhattacharjee were his students. The early biophysics efforts in Mumbai were led by A.R. Gopal Ayengar at BARC. Another pioneer in Mumbai was K.S. Korgaonkar who worked at the Cancer Research Institute. The early leaders of Biophysics in North India included R.K. Mishra of AIIMS and S.R. Bawa of the Punjab University, Chandigarh. Then of course, there was the GNR group in Chennai. After J.C. Bose, it was GNR who made the highest global impact from India in the broad field of Biophysics. From beginnings in handful of centres, Biophysics in India has now spread over scores of laboratories. Unlike in the case of crystallography, the Biophysics community is marked by extreme diversity.

The Indian Biophysical Society (IBS) was formed in Kolkata in 1965 on the initiative of N.N. Saha, under the presidentship of D.M. Bose. N.N. Saha led IBS as its secretary for nearly two decades. From a good beginning, the annual symposium of IBS began to become irregular. In the 1984 meeting at Hyderabad, organized by D. Balasubramanian, N.N. Saha was elected as the President of IBS with D.P. Burma as the Secretary. The next meeting was organized by S.R. Bawa at Chandigarh in 1985. In the absence of the President, Balasubramanian, the Vice-President, chaired the General Body meeting of IBS. D.P. Burma, the Secretary, was present at the meeting. For reasons which are not entirely clear to me, the General Body meeting ended in pandemonium. That marked the end of the first phase of IBS. In the meantime, N.N. Saha passed away in 1986. In any case, the major groups at Madras University, IISc and TIFR were not active participants of IBS.

After the Chandigarh fiasco in 1985, the groups at the Madras University, IISc and TIFR also began to take keen interest in the affairs of the IBS. After extensive consultations within the biophysics community, the next meeting of IBS was organized at the Banaras Hindu University (BHU) by P.C. Mishra in 1989. A new executive committee with R. Srinivasan of Chennai as President was elected at Banaras. The next annual symposium of IBS was held in its birth place, Kolkata, with S.N. Chatterjee, a Founder-member, as the main organizer. The 1991 meeting was in Chennai, organized by N. Yathindra. At this meeting, B.B. Singh of BARC succeeded Srinivasan as President. The meeting next year was organized by P.A. Damle at Pune. In the 1993 meeting at Ananthapur with V. Ramamurthy as the main host, I was elected as President to succeed B.B. Singh.

From the early 1990s, Girijesh Govil of TIFR and I worked together to guide IBS. Girijesh was the leader of the Mumbai group and is an NMR specialist. I, a crystallographer, was by then the Chairman of MBU/Biology Division at IISc. Both of us were of the same age group and had comparable statures in Indian science. Conventional wisdom has it that we should be competing. On the contrary, we worked in close co-operation to strengthen IBS and to enhance the role of India in the international biophysics community. To start with, we were bound together by our common interest in biophysics community. In course of time, we became close personal friends. For almost two decades, we together exerted considerable influence, often imperceptibly, on the affairs of IBS.

While the affairs of IBS were getting back on track, the same thing was happening in relation to the INSA National Committee for IUPAB also. Till the mid 1970s, Gopal Ayengar chaired the Committee. Since then, Obaid Siddiqi of TIFR and N.K. Notani of BARC chaired it. Both were distinguished scientists, but not conventional biophysicists. The situation changed when V. Sasisekharan became the Chairman of the Committee during 1985-88. He was followed by K.R.K. Easwaran, a recognized biophysicist, during 1988-91. I became the Chairman of the Committee in 1991.

That I was simultaneously President of IBS and Chairman of the National Committee helped in the consolidation of the activities of both the bodies. It was during this period that the annual Biophysics Symposium was held in 1994 at Chandigarh. That was the time when P.C. Mangal of the Punjab University was a Vice-President of IBS. The organizing Secretary of the symposium was M.P. Bansal. The symposium *inter alia* marked the closure of the unfortunate event that took place at the same venue in 1985. D.P. Burma was invited as the keynote speaker and D. Balasubramanian as an invited speaker. The participation in the Chandigarh meeting was much larger than expected. I believe that the 1994 Chandigarh meeting marked the emergence of IBS into a united, coherent, representative body of Indian biophysicists.

I have attended many of the subsequent annual meetings of IBS. I have vivid memories of each of these meetings. The 1996 meeting was held at Bengaluru with P. Balaram as the main organizer, to commemorate 25 years of MBU. The G.N. Ramachandran Lecture associated with each IBS annual meeting was initiated in Chennai in 2002. Yathindra was the main organizer of the meeting. The first GNR lecturer was Venki Ramakrishnan. This was long before he received the Nobel Prize. The community by then had recognized the potential of Venki as an outstanding scientist. Venki and I had known about each other, particularly through our common friends Guy and Eleanor Dodson. However, we met each other for the first time only in 2002 in Chennai. After the Chennai meeting, he visited Bengaluru as a guest of the Institute. I, as Associate Director, was his main host. I also took the initiative of arranging visits of Venki to the Institute as G.N. Ramachandran Professor. Since then, many global leaders of science have delivered the Ramachandran Lecture. I have already referred to my introducing Hartmut Michel who gave the lecture in the IBS meeting of 2004 at NIMHANS, Bengaluru, organized by Nanda and Preeti Joshi.

The last IBS meeting in which I gave a major talk was the one at Jamia Millia Islamia, New Delhi in 2015. The main organizer was Imtiyaz Hassan, a former student of Tej Pal and then a faculty member at Jamia. The 2015 meeting was meant to celebrate the golden jubilee of the founding of IBS. Furthermore, Tej Pal was then the President of IBS. For these reasons, I attended the meeting along with Kalyani, in spite of my indifferent health. Two Ramachandran lectures were delivered at the meeting, one by Girijesh Govil and the other by myself. I was deeply touched by this gesture of acknowledging our contributions in the revival of IBS and its subsequent efforts. During the meeting, part of the time, I was airborne in a wheel chair, carried by young students. All the same, it was wonderful spending time with old friends and colleagues. After that, I attended the meeting in Bengaluru, organized by Raghavan Varadarajan and others in 2016.

I cherish my association with IBS and the Indian biophysics community. I have had very pleasant association with many colleagues in the community. In addition to those whose names have already been mentioned, they include Motilal Maiti, Ravi Majumdar (both from Kolkata), Anil Saran, R.V. Hosur, and K.V.R. Chary (all from TIFR), K.P. Mishra (BARC), P.B. Vidyasagar, A.S. Kolaskar (Pune University), Faizan Ahmad (Jamia Millia Islamia), N.R. Jagannathan (AIIMS), C. Mohan Rao (CCMB) and Fateh S. Nandel (Chandigarh). Among them, the contributions of Anil Saran and Jagannathan to IBS and the community have been particularly noteworthy. Jagannathan and his family, over the years, became very close to me and Kalyani.

IUPAB, Congresses, Conferences

In the 1960s and 1970s, Gopal Ayengar and GNR were involved with IUPAB to different extents. After a long gap, Indians again began to play an active role in IUPAB from the 1990 Vancouver Biophysics Congress. At the Congress, Govil was elected to the Council of IUPAB. I became a member of the IUPAB Commission on Education and Development in Biophysics in 1991, and continued in that position till 1996. In addition to science, I also enjoyed my stay at Vancouver along with colleagues. Vancouver is a vibrant, cosmopolitan but an expensive city.

The visit I made to Moscow, a few months after returning from Vancouver, provided a study in contrast. I led a delegation on protein engineering, sponsored by DST. The Soviet Academy of Sciences was our host. Although we wanted to visit Moscow in summer, the visit actually took place in October, the beginning of Russian winter (In a parallel situation, the visit of my Soviet colleague Thumanyan to India took place in May!). The Soviet Union was in the throes of collapse and confusion prevailed all around, unlike in Vancouver. In Vancouver, we had to be very careful to live within the US$ 120/- provided as per diem. On the contrary, it was difficult to spend the 17 Rubles provided to each of us per day in Moscow. There was scarcity of goods, but when available, they were very inexpensive. In spite of the confusion, the stay in Moscow was enjoyable. As everywhere else, people were warm and hospitable.

The 1993 Biophysics Congress was in Budapest, the beautiful city bisected by blue Danube. INSA and the Indian delegation led by me as the Chairman of the National Committee had decided to bid for the 1999 Congress to be held in India. The normal practice is to bid six years ahead of the proposed Congress. The decision on the bid is taken by voting in the General Assembly consisting of representatives of the national adhering bodies. Our competitors in Budapest for the 1999 Congress were the Americans. There was a rumour that the Americans and the Chinese had made a deal under which the Chinese would support the American bid, in return for some reciprocal measure. It so happened that the first person I saw at the Congress venue was Liang Dong Cai, the leader of the Chinese delegation. He assured me his support for the Indian bid. We had supported the Chinese bid for the 1993 IUCr Congress in Beijing. Dong Cai said that it was now their turn to support the Indian bid for the Biophysics Congress. In any case, he would be uncomfortable in supporting USA against an Asian country like India. This conversation with Dong Cai put our minds at ease.

I presented the Indian case for the 1999 Congress in the General Assembly. The Americans had specially flown in Charles Cantor to present their bid. There was also a somewhat non serious bid by the Egyptians. The real competition was between India and USA. To our great satisfaction, we won.

After the Budapest Congress, I had a one off involvement with the International Union of Biochemistry and Molecular Biology (IUBMB). The 1994 Congress of IUBMB was held in New Delhi. I was a member of the Programme Committee. Wayne Hendrickson and I organized a very successful symposium at the Congress on protein structures. I also inaugurated and gave a major talk in a satellite symposium concerned with structural biology in Kolkata.

I did not attend the 1996 Biophysics Congress. However, I was elected as a member of the IUPAB Council, in the General Assembly associated with the Congress. Effectively, I replaced Govil whose membership of the Council had come to an end in 1996. I was also elected in 1996 to the IUPAB Task Force on Bioinformatics, which was partly responsible for my inclusion in the Inter-Union Bioinformatics Group (IUBG) of ICSU. I had described earlier the activities of IUBG.

I fondly remember my visit to Auckland in New Zealand in April, 1998 to participate in the IUPAB Council meeting whose main agenda was the preparation for the 1999 Congress in New Delhi. David Parry of the Massey University was then the President of IUPAB. After the Council meeting, I stayed for a couple of days as the guest of Ted and Heather Baker. They took me around to see the spots near Auckland. The stay in New Zealand was indeed very pleasant.

Soon after the Council meeting, we plunged into the preparations for the 1999 Congress which took place in September. Girijesh Govil, as the Chairman of the Organizing Committee, was the main person behind the preparation. Girijesh was particular that I should be designated as the Co-Chairman of the Committee. I was also the Chairman of the Programme Committee. The entire Biophysics community of India, INSA and DST were involved in the organization of the Congress. The Delhi colleagues like Tej Pal and Jagannathan were particularly involved in the organization. Noteworthy contributions came from Anil Saran and Easwaran as well. A volume entitled *Perspectives in Structural Biology* in hounour of

G.N. Ramachandran, edited by M. Vijayan, N. Yathindra and A.S. Kolaskar, was released at the inaugural function. Satellite meetings were held at Hyderabad and Kolkata, organized by A. Chattopadhyay and R. Mazumdar respectively. We had unstinted support from IUPAB secretariat as well. In this context, I particularly remember Tony (A.C.T.) North, my old Oxford colleague, who was then the Secretary General of IUPAB. In the General Assembly, Girijesh was elected as the Vice-President of IUPAB. I was re-elected to the Council. We thus had two Indians in the IUPAB Council! Two members from the same country in the Apex Committee of an ICSU Union is unusual.

The 2002 Biophysics Congress in Buenos Aires, Argentina was preceded by a meeting of IUPAB Council in London in February 2001. The main agenda of the meeting was the preparation for the 2002 Congress and discussions with the Argentinian organizers. I reached London on 9 February afternoon and left during the early morning of 12th. This was probably my shortest visit to England! Due to pressure of work at home, the only thing I did in England this time was to participate in the Council meeting. The visit to Buenos Aires to participate in the IUPAB Biophysics Congress of 2002 was a very interesting experience. That provided a fleeting familiarity with the ambience of Latin America. Buenos Aires is, of course, a beautiful city with much to offer. The scientific programme of the Congress was very interesting. My term as a member of the Council came to an end in the 2002 General Assembly. T.P. Singh was instead elected to the Council. Govil continued in the Council for another term after his tenure as Vice-President came to an end in 2002, again resulting in two Indian members in the Council. In subsequent years, N.R. Jagannathan and Mohan Rao also served on the Council. Thus, from 1990 till today, India was continuously represented in the IUPAB Council, often simultaneously by two members.

My active involvement with IUPAB almost came to an end with the Buenos Aires Congress. The next major international Biophysics Congress that I participated in was the 7th Asian Biophysics Association (ABA) Symposium which was held along with the Annual IBS meeting in New Delhi, in early 2011. I was the chairperson of the organizing committee. The whole event was organized under the leadership of Jagannathan. Kalyani and I were present in the deliberations throughout the meeting. I was to turn 70 later that year. Jagannathan organized a pleasant grand function chaired by R. Chidambaram to congratulate me. It so turned out that Ada Yonath was also present in the function. As mentioned earlier, she participated in the symposium at Bengaluru, when I turned 60. At the Delhi meeting, Ada promised me that she would be present in my 80th birthday celebration as well!

After a gap of nine years, I participated in the Biophysics Congress in Beijing in 2011. By then, I had visited Beijing a few times, but Kalyani had not. One of the reasons I enthusiastically accepted invitation for a talk in the Beijing Congress, was to take Kalyani along with me to this wonderful ancient city that I had come to admire. Liang Dong Cai was an active participant of the meeting although he was in the process of withdrawing from active service on account of old age. In the meantime, I got to know Zihe Rao (a Chinese Rao!), a former student of Dong Cai, reasonably well. Zihe occupied high positions in Chinese and world science. He belongs to a different generation from that of Dong Cai and does not appear to be over burdoned with notions of Afro-Asian solidarity and anti-imperialism! The participants in the Congress included Tom Steitz and Venki Ramakrishnan. Inevitably, we were active participants of the tour programme associated with the Congress, particularly as Kalyani was accompanying me. The spots we visited included the Tiananmen Square, the Forbidden City, the Summer Palace and the Great Wall, locations where I have been earlier more than once.

It turned out that the Beijing Biophysics Congress was the last major international meeting I attended abroad, although we did not know it at that time. Physical disabilities have a habit of arriving unannounced.

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INVOLVEMENT WITH ACADEMIES, PRESIDENT OF INSA

Background

Ancient and medieval India produced a rich tradition in science and technology. However, that tradition is not directly connected to the modern scientific enterprise in India. By the dawn of modern times, the hot springs of Indian intellectual creativity had dried up to a substantial extent. Modern science, as we know it today, is essentially a product of European Renaissance. It came to India along with European colonialists. The early development of modern science in India was not the result of the desire of the rulers to teach science to the Indian subjects. The early efforts of the British rulers were to survey the land and resources of India, with a view to exploit them. Within a decade of the 1757 Plassey War, which established the ascendancy of the British in India, Survey of India was established in 1767. The obvious aim was the consolidation of the territory acquired by the British. The Geological Survey of India was established in 1851, closely followed by the establishment of the Archeological and the Botanical Survey of India in 1861 and 1890, respectively. In the meantime, India Meteorological Department started functioning in 1875. The British also promoted English education in the country with the objective of utilizing the services of Indians at lower levels of administration and commerce. As an unintended consequence, a segment of Indians was exposed to modern science and western liberal ideas.

The region of India which first came under British rule was Bengal. Almost inevitably, Bengal, particularly Kolkata, became the spring board of Indian Renaissance inspired by a combination of Western liberal ideas and traditional Indian values. The Indian Association for the Cultivation

(L to R): C.V. Vishveshwara, Vijayan, Mrs. Chandrasekhar, S. Chandrasekhar during the Golden Jubilee celebrations of IASc in 1985 in Bengaluru.

Vijayan delivering the national Science day lecture in 2013 in the premises of NASI, Allahabad.

Taking over the Presidentship of INSA from R.A. Mashelkar

Presentation of INSPIRE panel report to Secretary, DST.
(L to R) : N. Mukunda, T. Ramasami, Vijayan, A.K. Sood and P.S. Goel.

Presenting INSA awards to Yash Pal, M.M. Sharma, Samir Brahmachari and Nirmal Ganguly.

Presenting INSA Fellowship to Chandrima Shaha.

Presenting memento to Prime Minister Manmohan Singh during the inauguration of the Platinum Jubilee celebrations of INSA.

Kalyani, Guy Dodson, Vijayan and T. Ramasami at the inaugural function.

With President Pratibha Patil at the concluding session of the Platinum Jubilee celebrations.

(L to R) : P.N. Tandon, M.G.K. Menon, Prithviraj Chavan, Vijayan and H.Y. Mohan Ram at the release of the book "Science in India: Achievements and Aspirations".

Steven Chu with M.G.K. Menon and Vijayan during his visit to INSA.

Steven Chu during his visit to INSA.
(L to R): Ramasami, A. Surolia, Steven Chu, Vijayan, S.K. Joshi and R. Rajaraman.

Induction of Torsten Wiesel as Foreign Fellow of INSA
Front row (L to R) : Alok Moitra, D. Balasubramanian, Vijayan, S. Varadarajan, Wiesel, his companion, N.K. Gupta and R. Rajaraman
Back row (R to L) : Samir Brahmachari, Alok Bhattacharya, Akhilesh Tyagi.

With Volker Ter Meulan, President, Leopoldina Academy of Germany.

With Lu Yongxiang, President, Chinese Academy of Sciences

With employees of INSA. Vijayan is flanked by S.K. Sahni and Alok Moitra of Science (IACS) was founded in Kolkata in 1876 by Mahendralal Sircar. This was the first scientific organization to be established on Indian initiative. IACS became a centre of vibrant scientific research after C.V. Raman entered its portals in the early years of the 20th century. Early giants of Indian science included J.C. Bose and P.C. Ray, both friends of Rabindranath Tagore. All of them were driven to a substantial extent by nationalism. An instance of the national sentiment was the refusal of C.V. Raman to comply with the condition of foreign training associated with the Palit professorship of the Calcutta University. The next generation of science leaders in India, like M.N. Saha, S.N. Bose and K.S. Krishnan, were also staunch nationalists.

The second scientific organization to be established in India by Indians was the Indian Institute of Science, Bengaluru in 1909. That resulted from the sustained efforts of J.N. Tata, motivated by nationalistic urges, and the munificence of the then Maharaja of Mysore. The Indian Science Congress Association was established in 1914 on the lines of the British Association. The early decades of the 20th century witnessed the emergence of a viable scientific community in India. In the 1920s and 1930s, there was considerable discussion on the formation of a science academy in the country. Eventually, for reasons that we need not go into here, three such academies were established in the 1930s. Historically, the first academy to be established was the National Academy of Sciences (India) (NASI), in Allahabad in 1930 with M.N. Saha as its first President. C.V. Raman established the Indian Academy of Sciences (IASc) in Bengaluru in 1934. Nearly at the same time, he also started *Current Science* which played a major role in opinion formation in the Indian scientific community. Finally, the National Institute of Sciences of India (NISI) was founded on the premises of the Asiatic Society in Kolkata in early 1935 with L.L. Fermor as its first President. During the late 1940s and early 1950s, NISI moved to New Delhi, the national capital of India. In 1970, NISI was renamed as the Indian National Science Academy (INSA). Over the years, the academies and the relationships among them evolved. I have witnessed this evolution at close quarters after I became Fellow of the three academies; IASc in 1983, INSA in 1987 and NASI in 1990. All the three academies are now vibrant and well organized, and work in close cooperation among themselves. I was elected to The World Academy of Sciences (TWAS) in 2002.

Indian Academy of Sciences

C.V. Raman was the President of IASc from its inception till 1970 when he passed away. Since then, the President and the Council changed every three years. I was elected to the Academy at the fag end of the term of S. Varadrajan as President and joined the Fellowship at the beginning of Ramaseshan's term. The activities of IASc are characterized by their high academic content. The annual meetings, usually held in November, are marked by the high standard of the proceedings. Family members are encouraged to accompany the

Fellows. That naturally enhanced the camaraderie among the Fellows and their families. My first annual meeting was in Pune NCL in 1983. The new Fellows elected in 1983 included Ramesh Mashelkar, Ramanath Cowsik and K.J. Rao. Years later, I happened to see again the group photograph taken on the occasion of the 1983 Pune meeting. I was standing in a back row, flanked by young Ramesh Mashelkar and Goverdhan Mehta, with both of whom I had much to do in my later career. On that occasion, when I spoke in the NCL auditorium, I did not realize that I would have the opportunity to speak in the same auditorium several times in the future. P.N. Tandon was also elected to the Fellowship of IASc in 1983, although by then he was already a well recognized senior surgeon and scientist. I met him for the first time at Pune in 1983. I also vividly remember the presentations made by S.Z. Qasim and his colleagues on their Antarctic expedition.

Another experience, unconnected with science, which I remember occurred when K.J. Rao and I were travelling by train from Bengaluru to Pune for the 1983 meeting. We had the Congress leaders Mallikarjuna Kharge and Dharam Singh for company in our cabin, during part of the journey. We had pleasant conversation with them. (It was a pleasure to listen to Rao's impeccable Kannada! I stuck to English). What struck me was the facility with which the two leaders switched between Kannada and Hindi in the conversation between them. For a few minutes they spoke in Kannada; when they resumed the conversation after a pause, they could well be speaking in Hindi. Sometimes, one spoke in Kannada and the other responded in Hindi. This facility to unconsciously switch between Kannada and Hindi was an indication of the cultural diversity and richness of North Karnataka.

The first time I got seriously involved in the work of the Academy was in the context of the organization of the Golden Jubilee meeting in Bengaluru. The meeting was originally scheduled for November, 1984. However, the meeting had to be postponed on account of the assassination of Indira Gandhi in October. The Golden Jubilee meeting was eventually held in February, 1985. Among other things, I had special responsibility for transport and accommodation. The task was particularly difficult, as the participants included many senior Fellows whom we had specifically invited for the historic occasion. I was ably assisted in that task, among others, by Raghavendra Gadagkar, S. Chatterjee (later at the Indian Institute of Astrophysics, Bengaluru) and Vani Chatterjee, all then young scientists. The Golden Jubilee meeting was a grand affair with the Nobel laureate S. Chandrasekhar as the main speaker. The cultural programme associated with the meeting included performances by M.S. Subbulakshmi, Padma Subramaniam and Yakshagana Hegde on different evenings. Some felt that the grandeur of the cultural programme even overshadowed the outstanding quality of the scientific programme!

The 1986 annual meeting was at Varanasi. I attended the meeting with Kalyani and Devi.

On the way to Varanasi we visited Allahabad for a couple of days. We were looked after at Allahabad by Krishna Misra of the Department of Chemistry of Allahabad University and her student Ramendra Singh. I was very pleased to have been able to show Kalyani and Devi my Alma mater and other interesting locations in Allahabad. The programme of the Varanasi meeting included a symposium organized by me on macromolecular structures. The programme organized for accompanying members enabled Kalyani and Devi to visit many historic locations in and around Varanasi. The 1988 annual meeting was special as it coincided with the birth centenary of C.V. Raman. Appropriately, the meeting was held at IACS, Kolkata. Again, I attended this meeting with Kalyani and Devi. An attraction of the meeting was the participation of the Prime Minister Rajiv Gandhi in it for a ceremonial occasion. During the Kolkata meeting, S. Krishnan (NAL, RRI) and his family and ourselves stayed in the same building that served to further strengthen the strong bonds which already existed between us.

As could be seen from the foregoing, I was fairly active in the Academy affairs during the first few years of my induction into it. My involvement with IASc became deeper after I was elected to the Council in January 1989. I served on the Council for a total of nine years in two instalments. In the first instalment, spanning six years (from January 1989 to December 1994), I worked with two Presidents, C.N.R. Rao and Roddam Narasimha. When K. Kasturirangan became the President in 2001, he wanted me to be on the Council with him. Thus, I again served on the Council for a second time. At different times, I have also served on many Academy Committees, including as the Chairman of the Sectional Committee on Biology. My association with the Academy has been so diverse that it is difficult to touch upon all its aspects. The role of the Academy staff in ensuring the smooth conduct of the activities has been remarkable. For a long time, G. Madhavan, the Executive Secretary, was synonymous with the Academy. Madhavan was succeeded by G. Chandramohan. Happily, both of them continued to be associated with the Academy after their formal retirement.

I have tried to attend, fairly successfully, all the annual meetings and the mid-term meetings during my membership of the Council. The annual meetings that I attended during the first instalment of my membership of the Council were those held at Bhopal (1989) Pune (1991) Ahmedabad (1992) and Bengaluru (1994). During the second instalment, I attended the meetings at Chandigarh (2002) and Guwahati (2003). Kalyani accompanied me to the Guwahati meeting. At other times, I attended the annual meetings when I had a specific role. I was at the Chennai meeting in 1995 to speak in a symposium associated with the annual meeting on “100 years of X-rays and 50 years of NMR”, organized by P.T. Manoharan. At the Kottayam meeting in 1998, to which Kalyani accompanied me, I gave a special lecture. I was in Goa in 2000 as a speaker in a symposium on Genomics in the annual meeting. I have very pleasant memories of each of the annual meetings that I attended. All of them were scientifically vibrant. Cultural programmes and visits to interesting places were also associated with all of them. In annual meetings, considerable discussions often took place on policy issues as well. I particularly remember the discussion on the Narmada valley project at Bhopal and that on dwindling support for science at Ahmedabad.

Publication of journals is at the core of the activities of IASc. The editorial staff at the Academy is as good as I have seen anywhere. I have occasionally published in the *Journal of Biosciences*, but my main involvement as a contributor was with *Current Science*. In the early years of my independent career, we often published the first preliminary result of a structural work in *Current Science* to establish priority, before proceeding to write a detailed paper. *Current Science* has been a major instrument for establishing priority. One of the important structures we solved in the 1990s was that of a complex between peanut lectin and the tumour associated T-antigen. We got wind that an American group was also working on the same problem. Therefore, as soon as we established the structure, we published the result in *Current Science*. I recall Balaram, the then Editor, mentioning that, the particular paper contributed to increasing the citation index of the journal that year!

In addition to its scientific content, *Current Science* to a substantial extent has been a house journal of the scientific community of India. Many important issues are thoroughly discussed in the columns of the journal. I particularly recall the discussion on the precipitous fall of support for science in India in the early 1990s. An article I wrote on the subject in 1992 was probably my first contribution on policy issues published in *Current Science*. Since then, I have continued to write general articles in the journal. My closeness to the journal extended to its Chief Editors as well. The yeomen services rendered by S. Ramaseshan and P. Balaram are well known. Both these names occur frequently in this narrative. The present incumbent S.K. Satheesh is an outstanding scientist. I first came to know of him from A.P. Mitra when I was a member of ADCOS. Subsequently, I was involved in his appointment at IISc when I was the Associate Director. I have often been touched by the consideration Satheesh has shown to me.

On account of the geographical proximity and personal relationship with the concerned people, the Indian Academy of Sciences has been a constant presence in my academic consciousness.

National Academy of Sciences (India)

I was elected to the Fellowship of NASI in 1990. I was not even aware that I have been nominated to the Fellowship. I was informed about my election by C.L. Khetrapal during the Biophysics Congress at Vancouver in 1990. NASI was then at a stage of resurgence. My first significant role in NASI was as the President of the Biology section in the Lucknow annual session in 1998, when P.N. Tandon was the President of NASI. I was deeply touched by the invitation of Tandon to me to be the Sectional President.

I was a member of the Council of NASI for six years from January 1999 to December 2004. I was its Vice-President during the last two years of my council membership. During the six year period, V.P. Sharma, S.K. Joshi and J.P. Mittal were the Presidents (the NASI Council has a two year-tenure). Among others, M.G.K. Menon, P.N. Tandon and Manju Sharma were the guiding lights in the Council. M.S. Sinha was the Executive Secretary, on whose untimely demise, Niraj Kumar took over the position. I have very pleasant memories of my association with NASI. The overall ambience was very homely without, of course, sacrificing scientific rigour. To me, each trip to Allahabad was akin to home coming, as my interest in science essentially started when I was a student of Allahabad University. It was wonderful spending time at familiar locations inside and outside the University and with old friends and acquaintances. I enjoyed the U.P. ambience in which I always felt comfortable and at home.

The annual sessions of the Academy were always scientifically rewarding. I attended those at Lucknow (1998), Allahabad (2000), Pune (2001), Ahmedabad (2003) and Jaipur (2004). Kalyani accompanied me to the Jaipur session. Each session was associated with cultural events and sight seeing as well. The Allahabad meeting in 2000 was special as it marked the 70th year of the foundation of the Academy. Another important event I remember well is the opening of the new NASI building at Allahabad by M.M. Joshi in 2003. I also took the initiative in arranging a symposium on macromolecular crystallography in Hyderabad during November 2005, as part of the Platinum Jubilee celebrations of NASI. The symposium was organized by Seyed Hasnain, the then Director of CDFD, and Shekhar Mande.

After a gap of several years, I visited Allahabad along with Kalyani in February-March 2013. NASI had given me the Krishnaji award that year. Krishnaji was my teacher in the Allahabad University. I thought it was appropriate to accept the award and give the lecture in the Allahabad University, which I did. I deeply appreciated the gesture of my old teacher Suresh Chandra in coming all the way from Varanasi, in spite of indifferent health. He introduced me at the award giving function. In addition to the lecture at the University, I also gave the Science Day Lecture at the Academy. Only when I was about to start the lecture, I realized that most of the audience were students from Hindi medium institutions. To my own surprise, I gave most of my talk in Hindi! Our visit to Allahabad was concluded with a conducted tour of the Kumbh Mela site by a couple of kind colleagues from the office of NASI. I guess that was an appropriate way to sign off from my last piece of work in Allahabad!

After my formal retirement in 2004, I have been successively DBT Distinguished Scientist/ Professor, DAE Homi Bhabha Professor and INSA Albert Einstein Professor. After the last mentioned professorship came to an end, NASI very kindly provided me with a NASI Platinum Jubilee Senior Scientist position. Thus, my association with the Academy continues.

Indian National Science Academy. A saga of long association

In terms of the size of the establishment and range of activities, INSA is larger than the other two Academies. Although all three Academies are equally close to my heart, my involvement with INSA has been more intense. At a personal level, INSA Guest House has been a refuge in Delhi for all Fellows including myself, from the time I was elected to the Fellowship of the Academy! The Guest House became a more comfortable abode after S. Varadarajan constructed the impressive new building of INSA. Located at the heart of New Delhi, INSA Guest House is at a convenient location to reach different scientific and academic institutions in the national capital. The ambience of the INSA Guest House and the associated dining facilities have always been very homely. To many of us the INSA Guest House has been a home away from home.

My first formal association with INSA was as a member of the National Committee for IUCr during 1985-88. During 1991-94, I functioned as the Chairman of the National Committee for IUPAB. I also functioned as the Chairman of the combined National Committee for IUCr and IUPAB during 2004-2008. My involvement with IUCr and IUPAB at the international level from the middle of 1980s meant constant interaction with the ICSU section of INSA. I also served on the Sectional Committee on Biochemistry, Biophysics etc. during two separate terms, including as the Chairman of the committee during the second term. I served as the Convener of the Bengaluru chapter of INSA. During that period, I was also a member of the Council of IASc. Taking advantage of this dual responsibility, I organized a very interesting INSA-IASc discussion meeting at Bengaluru in 1989. That was perhaps my first contribution to the efforts towards establishing working relations among the three science academies of India. I have also participated in other scientific symposia organized by INSA, well before I became an office bearer of the Academy.

I have been a beneficiary of the various programmes of INSA from the beginning of my association with it. In 1986, I visited several laboratories in England as part of the INSA-Royal Society Exchange Programme. I was awarded the G.N. Ramachandran medal of INSA in 1994. I received the award and gave the award lecture at an INSA general meeting at Pondicherry when S.K. Joshi was the President. The J.L. Nehru Birth Centenary Visiting Fellowship of INSA enabled me to again visit many laboratories in England in 1999. Yet another recognition conferred on me by INSA was the K.S. Krishnan Memorial Lecture Award of 2001. Much later, I was INSA Albert Einstein Research Professor during 2013-2018.

Vice-President of INSA

I was elected to the Council of INSA in 2004 and assumed office as Vice-President in charge of Fellowship Affairs in January 2005. I worked closely with Ramesh Mashelkar who became the President at the same time. During my tenure as Vice-President, Anupam Varma was the Vice-President in charge of Resource Management. I worked with him closely and a special bond developed between us. Raghavendra Gadagkar, Rajinder Jeet Hans Gill, Sudhir Sopory, S. Sivaram, Subhash Lakhotia, N. Balakrishnan (Balki), Alok Gupta, P.K. Kaw and Tej Pal Singh were Vice-Presidents along with me at different times during this period. The three year tenure of the last four spilled into the period of my Presidency, as the rules and regulations of the Academy wisely provided for stagger in the tenures of office bearers. I was already reasonably familiar with the staff of the Academy. My association with them became stronger after I became a Vice-President. S.K. Sahni was the Executive Secretary of INSA during most of my close association with the Academy. Sahni is a person with extraordinary competence and commitment to the Academy. For a long period, he was the most visible face of the Academy. He was ably assisted, may I say complemented, by Alok Moitra who went on to succeed Sahni as the Executive Secretary. I have had close interactions with the other officers and staff of the Academy as well.

By the time Mashelkar was elected President and I a Vice-President of INSA, we had known each other for more than two decades and were on first name terms. Among other things, we had also worked together earlier in the Council of IASc. Therefore, my rapport with him was perfect. Among the Vice-Presidents, the one responsible for Fellowship Affairs has a predominant role on occasions like to the induction of Fellows into the Academy. In any case, perhaps imperceptibly, I came to be looked upon as the number two to the President. I have also occasionally stood in for him in his absence. I have been deeply involved in the initiatives he took and I cherish the association I had with him, while working for INSA.

Mashelkar took particular interest in policy matters and in bringing the science academies together. In this context, I particularly remember a joint meeting of INSA and IASc at Bengaluru on education. I represented INSA in this meeting. IASc already had a very vibrant education programme, thanks to the outstanding leadership of N. Mukunda. My close association with both the Academies helped in smoothly establishing the relation between INSA and IASc on the education programme. INSA also became part of the summer students and teachers programme. NASI also joined the programme.

An important step taken by INSA during this period was the revival of the Honorary Scientist programme in 2006. I was involved in the selection of the new Honorary Scientists under the revised programme. We chose Sriramachary and Mohan Ram as the first set of Honorary Scientists. I deem it an honour to have been associated with this selection as I hold both of them in the highest esteem. An attempt was also made to rationalize different INSA awards, with the help of P. Rama Rao. Well meaning but arbitrary use of endowment funds often leads to utter confusion. The effort was to bring some order, including financial order, in the management of INSA awards. This effort was completed during my Presidency.

Another event which I distinctly remember is the meeting of the leaders of Academies held in Beijing in April 2006 at the invitation of the Chinese Academy of Sciences (CAS). Girijesh Govil and I represented India. The meeting helped in strengthening the relations between the Chinese Academy and INSA. We also could learn from the experiences of the academies represented in Beijing. As always, the Chinese hospitality was overwhelming. After the Beijing meeting, the Academy also arranged for me to visit Shanghai where most of the earlier insulin work was done. The Shanghai visit was thoroughly enjoyable except for the incessant rain which somewhat dampened the enthusiasm!

In Beijing, Girijesh Govil and I had detailed discussions with the leaders of the Chinese Academy and a blueprint was drawn up to upgrade the relation between INSA and CAS. In pursuance of the discussions in Beijing, we organized an INSA-CAS workshop on Structural Biology in Bengaluru in December 2007. A strong Chinese delegation led by Jinghai Li, Vice-President of CAS, participated in the workshop. All the leading structural biologists of India participated in the meeting. There were two keynote lectures, one by a Chinese and the other by an Indian. The Chinese lecturer was Rui-Ming Xu, a distinguished scientist who had just returned to China from the US. We fielded Samir Brahmachari who had just taken over as DG CSIR. This was probably Samir's first formal appearance as DG CSIR at IISc, his Alma mater!

The Academy Council meets four times a year. The April/May and August meetings are usually held at the headquarters. The October and December meetings are usually held at different centres in the country. Each Council meeting is accompanied by a general body meeting and different Academy programmes. The most important general body meetings are the Anniversary meetings held every year in December. The first Anniversary meeting after I became the Vice-President was at CCMB/IICT, Hyderabad, a very familiar ground. The 2006 meeting was at Mumbai. The Council meeting was hosted by BARC. The main event was held at the University Department of Chemical Technology (UDCT), subsequently renamed as Institute of Chemical Technology (ICT). As part of it, the meeting had the celebration of the 70th birthday of M.M. Sharma. Probably on account of that, Mukesh Ambani, a student of Sharma, took keen interest in the organization of the meeting. M.M. Sharma saddled fundamental research and industrial consultation with equal ease. I have been particularly close to him and have had several interactions with him. M.M. Sharma is a strong personality with a kind heart. The Anniversary meeting in 2007 at Goa, organized by the National Institute of Oceanography, was very special to me. It is in that meeting that I was formally installed as the President of INSA. Kalyani accompanied me to the meeting.

Election as President of INSA

The possibility of becoming President of INSA had crossed my mind by the middle of 2006. However, I did not entertain the idea seriously. It was Tej Pal Singh who really planted the idea firmly in my mind, towards the end of 2006. Election to any position involves some campaigning. Much of the campaigning was also managed by Tej Pal. Perhaps more importantly, he kept me steadfast in the pursuit of the Presidentship. On a couple of occasions, two of my close friends appeared to be interested in the position. I was wary of competing with them. Tej Pal was among the most prominent of my colleagues who convinced me that these two friends were unlikely to succeed in their attempts and that I should be firm in my resolve to compete for the Presidency. Samir Brahmachari also had the same view. In the event, by the time the election took place in the Council, my choice was almost unanimous. To be elected the President of INSA is a great honour. To reach that position with the overwhelming support of colleagues is indeed satisfying as well as humbling. It was with a new sense of responsibility that I sat on the President's Chair in the all too familiar Council Chamber of INSA. The Council Chamber is adorned with the photographs of all the past Presidents who included many veterans of Indian science. I felt particularly humbled when I glanced through those photographs.

The team

Throughout my three year term as President, Ajay Sood and N.K. Gupta were the Vice-Presidents in charge of Fellowship Affairs and Resource Management, respectively. I have had very close relationship with them. Ajay is among the most outstanding of Indian scientists and has a high profile. He was concurrently the President of IASc during the final year of his Vice-Presidentship of INSA. However, that did not in any way affect his smooth functioning at INSA. N.K. Gupta is a very distinguished scientist. He is a strong and silent type. He stood by me on every single difficult occasion. Tej Pal continued to be the Vice-President in charge of International Affairs for two years. He was succeeded by N. Sathyamurthy. The two Vice-Presidents successively in charge of Science and Society during my term were N. Balakrishnan and Mahtab Bamji. A.K. Gupta and Akhilesh Tyagi looked after Publication and Informatics as Vice-Presidents during that period. P.K. Kaw and R. Rajaraman successively handled Science Promotion as Vice-Presidents. Mahtab was hesitant to accept the position but I persuaded her by insisting that I needed an elder sister in my team! Rajaraman is professionally and in other ways senior to me. I was deeply moved when he agreed to serve as a Vice-President in my team. As indicated earlier, S.K. Sahni and Alok Moitra from the Secretariat

Presidents of Indian National Science Academy
(L to R) : Goverdhan Mehta, A.K. Sharma, M.G.K. Menon, M.M. Sharma, M. Vijayan, P.N. Tandon, S.K. Joshi, S. Varadarajan and R.A. Mashelkar.

Felicitating the Past Presidents of Indian National Science Academy
R.A. Mashelkar, S.K. Joshi, Goverdhan Mehta and S. Varadarajan.

(L to R): K. Kasturirangan, S.K. Sahni, Jairam Ramesh (Minister of Environment & Forests), M. Vijayan and P.N. Tandon at INSA premises.

P.N. Tandon and M. Vijayan presenting a bouquet to Prof. Kapila Vatsyayan, Member of Parliament.

were pillars of strength. Most other officers also performed very well. I particularly remember Sunil Zokarkar who handled finance.

INSA has a semi-autonomous outfit dealing with History of Science. It publishes the *Journal of History of Science*. It also supports research on history of science. Work in the area is overseen by the Indian National Commission for History of Science, chaired by the President of INSA. The work is effectively supervised by the History of Science Research Council. During the first phase of my presidentship, R. Narasimha was the Chairman of the Research Council. After a period of long and distinguished service, Narasimha wished to be relieved. We replaced him with Raghavendra Gadagkar. For a long time, it was A.K. Bag who effectively led the activities of INSA related to history of science. I enjoyed working as the Chairman of the Commission, as it introduced me to an important area with which I only had vague familiarity. Part of the history of INSA itself can be gleaned from the Biographical Memoirs of deceased Fellows of the Academy. The publication of the memoirs was tardy for a period of time. V. Ramamurthy of IIT Madras put it on track through consistent hard work and devotion.

I relied heavily on the wisdom of past Presidents, when leading the activities of INSA. In addition to informal consultations, I used to have formal meetings of past Presidents every year. The help from past Presidents located in Delhi was particularly useful. The seniormost past President then was M.G.K. Menon who radiated nobility. Varadarajan maintained an office in the INSA building, the construction of which was his pet project. S.K. Joshi, my former teacher, was always available for help and advice. Among the past Presidents, the one who influenced me most was P.N. Tandon. He stood by me through thick and thin. Although not a past President, Mohan Ram, a doyen of Indian science, was always ready to help. I also recall the help I received from the then DST Secretary, T. Ramasami whom I had by then known for decades. By then, I was also deeply involved in the activities of DST. The partnership between Ramasami and myself helped smoothen many situations.

Core functions, organizational matters

A major function, perhaps the major function, of any science academy is the identification and promotion of excellence. Excellence is rewarded by the academies primarily through election to the Fellowship. This is also done by means of various awards and medals. INSA has, over the years, developed a robust system for election to the Fellowship and for choosing scientists for awards and medals. The main responsibility of any President is to preserve the system with appropriate incremental modifications. During my tenure, the sectional committees were reorganized on the basis of the recommendations of a committee headed by S.K. Joshi. This did not involve a total revamp of the system, but only changes in the allocation of areas to take care of modern developments. It was felt that we were electing too few Fellows each year, in relation to the large number of aspirants. Therefore, we upwardly revised the maximum number of Fellows to be elected each year, to 35. It is important to enable Fellows of INSA to work as long as they are active. In this context, all restrictions on INSA Senior Scientists and Honorary Scientists positions in terms of available vacancies and age of incumbent were removed.

The services of Past Presidents were extensively utilized for the election of Foreign Fellows and the selection of Research Professors. Incidentally, in the first year of my Presidentship, we elected Venki Ramakrishnan as a Foreign Fellow. At that time, he was not very well known except among structural biologists, and there was at least one adverse comment on Venki's election. I said that this is one case in which I had no doubt about the quality of the candidate. Venki got the Nobel Prize next year and many congratulated me for electing him to the Fellowship ahead of his receiving the Nobel Prize.

The October Council meetings usually have light agenda and therefore are often held at different locations in the country. However, the Council meeting of October 2008 was held at the headquarters itself as we were busy with the preparations for the Platinum Jubilee celebrations in 2009. The October Council meeting of 2009 and 2010 were held at Bhuvaneshwar and Thiruvananthapuram, respectively. Kalyani accompanied me to both the meetings. The Bhuvaneshwar meeting was hosted by T.K. Chandrashekhar, the then Director of NISER. It was a pleasure interacting with my old IISc friend Nayak who was then at NISER. Strangely, this was our first visit to Orissa and we took some time off for sightseeing. Thiruvananthapuram was of course familiar territory. The 2008 Anniversary meeting was postponed to coincide with the inauguration of the Platinum Jubilee celebration in early January of 2009. The 2009 Anniversary meeting was held along with the concluding function of the celebration. The 2010 Anniversary meeting, where I laid down office, was appropriately held at IISc, Bengaluru with Dipankar Chatterji, the then Chairman of MBU, as the main organizer.

While the academic activities of INSA proceeded with due diligence and dignity, there were some nagging establishment issues at the headquarters. More than half the employees were in litigation with INSA. There were several factors which led to this situation. The difficulties were compounded by different, somewhat contradictory court judgments. There was also confusion in the appraisal of the situation among the leadership of INSA and the officers of DST, the administrative department of INSA. One major issue at stake was the autonomy of INSA. The service benefits of the employees of the Government are better than those of the employees of autonomous organizations. In as much as INSA is funded by the Government and follows the overall organizational structure prescribed by the Government, some employees argued that INSA employees should be treated on par with Government employees. This argument was not acceptable to DST. Different judicial pronouncements could be interpreted in favour of or against the arguments of some of the employees. While we were very keen on maximizing the benefits to our employees, we could never concede that INSA is a Government organization. Treating it as an integral part of the Government would knock out the *raison d'etre* of the Academy. As it had lingered on for long and as many *ad hoc* solutions were attempted in good faith, the problem had become intractable by the time I assumed the Presidentship. There was so much bitterness that anonymous letters with various allegations flew thick and fast. DST itself had a voluminous file on the subject.

I was aware of the gravity of the employees' problem, even before I assumed the Presidentship. That was a main topic of discussion when T. Ramasami and I had a working dinner at the India International Centre on the eve of my assuming office, true to form, I received an RTI enquiry asking what we discussed at the meeting!). Through a series of discussions, we ultimately unraveled the issue. The colleagues who consistently worked with me on this issue were Anupam Varma, Tej Pal and Krishan Lal, in addition to Sahni and Alok Moitra. I understand that Ramasami had the benefit of advice from S.B. Krishnan, a former Financial Advisor in DST. Eventually through a judicial mixture of the exercise of autonomy by INSA and authority by DST and selective amnesia by both the organizations, solutions could be found for the problems. The suspicion in the minds of the employees was so deep that it took time and a carrot and stick approach to convince the employees that the solutions are good for them. Eventually, most of the employees were happy with what they got. They also agreed to withdraw the cases from the court. When I relinquished office, only one case was pending in the court. By that time, I had very cordial relationship with most employees. I hosted a farewell tea for the employees. Later on, I was told that I was the first President to do so!

Inter academy and policy initiatives

By the time I became the President of INSA, an ambience of collaboration among the three science academies of India had already been established. I had earlier contributed in small measures to developing this ambience. Inter academy cooperation was further strengthened during my Presidentship. This cooperation was particularly evident in relation to education and training. The administrative responsibilities of the education programme rested with IASc. The other two academies actively participated in it. N. Mukunda led the programme with brilliance and dedication. I also particularly remember the outstanding contributions of Subhash Lakhotia to the programme. A document on Restructuring Post-School Science Teaching Programmes, was jointly prepared by the three Academies. Refresher courses on various topics jointly organized by the three Academies have now become an important component of training of Indian scientists. What excited me most was the Summer Students and

Teachers Fellowship Programme. Hundreds of students and dozens of teachers worked each year in well established laboratories under well known scientists. I had occasion to address and interact with fellows at Bengaluru and New Delhi, more than once. They were exhilarating experiences.

The INSPIRE programme of DST, conceived, initiated and nurtured by Ramasami, is now very well established. When the programme was initiated, he requested me to involve the three Science Academies and the Indian National Academy of Engineering in organizing the academic component of the programme. With that, we brought the Engineering academy also in the ambit of inter academy programmes. This could be done smoothly partly because P.S. Goel, an old friend and also a distinguished Fellow of INSA, was then the President of the Engineering Academy. The inter academy involvement in the INSPIRE programme is now firmly established. The administrative responsibilities for the efforts largely rest with INSA. I recall that I participated in the first EFC meeting concerned with INSPIRE in the North Block, the only time I have entered the powerful precincts of the Finance Ministry! Normally, the concerned secretary chairs the EFC meeting. As a nice gesture, Ramasami requested the Expenditure Secretary to chair the meeting and fielded me, the President of INSA, as the opening speaker. In spite of some initial apprehensions, the meeting went off smoothly.

The next effort was to bring in the academies concerned with agriculture and medicine also under the ambit of inter academy programmes. An opportunity for doing so occurred when the six academies were requested by Jairam Ramesh, the then Minister of Environment, to prepare a report on GM Crops. The work proceeded smoothly, but an unfortunate slip occurred in the drafting process. We knew the origin of and the responsibility for the slip. However, the appropriate thing to do was for the Presidents to own up the responsibility and make necessary changes. Although the report was meant for limited circulation, understandably in retrospect, it turned out to be a subject of much public discussion. Even after owning up the slip, which was concerned only with a description, and appropriately modifying the report, virulent criticisms continued. Later on, our colleagues in international bodies told that any suggestion for considering GM crops as part of the food security package, would anyway have elicited concerted attack from interested parties.

I have only very briefly summarized the GM crop episode. It had a devastating effect on many of us, when it occurred. Now a decade later, there is no point in giving a blow by blow account of what happened then. In my mind, many were exposed, in the positive as well as the negative sense, for what they were. In any case, I suspect that gene editing technologies, which do not involve the introduction of foreign genetic material, would probably supersede the GM technology.

M.S. Swaminathan organized an 'Academy Summit' at the Science Congress in Chennai in January 2011. I had just relinquished my

Presidency, but he insisted that I should participate and speak in the summit. I was very pleasantly surprised when while introducing me, Swaminathan complimented me for taking the lead in preparing the Inter Academy report on GM crops. That certainly enhanced my own appreciation of the usefulness of the report. Earlier, when the controversy on the report was raging, I thought about requesting Swaminathan for help, not necessarily in support of us, but to soothen the situation. However, I decided against it. Swaminathan is an iconic figure who has never ceased to inspire me. Although the temptation was high, I did not want to drag him into a controversy. However, everyone did not show this consideration to the grand old scientist. An impression gained ground that Swaminathan is not favourably disposed towards GM technology. Eventually, he made his position unambiguously clear through public statements. He did the favour of sending me in December 2018, a statement for circulation among the concerned persons. In that statement, he wrote

"Genetic engineering technology has opened up new avenues of molecular breeding. What is important is not to condemn or praise any technology, but to choose the one that can take us to desired goal sustainably, safely, and economically.

Genetic modification is the technology of choice for solving abiotic problems like draught, flood, salinity etc. This is particularly important in the context of climate change. It may not be equally effective in the case of biotic stresses since new mutants of pests and diseases arise all the time."

The views enunciated above resonated well with the recommendations contained in the Inter academy report. Like many others, I highly value and respect the views of Swaminathan. To me, the clear enunciation of Swaminathan's position, which was substantially in tune with our recommendations, served as a closure of the GM technology episode.

INSA enjoys considerable prestige, although it is not endowed with raw power. Our efforts were to convert this prestige into useful influence and for strengthening its role as a think-tank in the service of the nation. Authoritative documents on several issues were prepared after due deliberations including seminars and symposia. I was particularly concerned about the structure of Indian science. It was necessary to examine the structure carefully to make it equal to the requirements of modern scientific research. While welcoming the Prime Minister at the inaugural function of the Platinum Jubilee events on January 10, 2009, I said "In order to unleash the creative potential of Indian Science, we need a vibrant, resilient and sensitive system which is less bureaucratic, less hierarchical, more autonomous and more participatory". I followed it up with communications to different agencies containing specific suggestions. Even after my term as INSA President was over, I continued to write in *Current Science* on the structure of Indian science. All these efforts had some modest impact on some segments of the scientific enterprise. The structure of Indian science has many positive as well as negative features. Our attempt should be to preserve and strengthen the positive features and eliminate or at least weaken the negative ones.

Presidentship of INSA involved the membership or the chairmanship of many committees, some dealing with policy issues. For instance, President of INSA is a member of SAC-C. I also was in an Apex Committee for formulating Plan proposals. Involvement in different important committees gave the INSA President some influence in formulating policy and decision making processes.

Platinum Jubilee

2009 was the Platinum Jubilee Year of INSA and a major responsibility of mine was to organize the celebrations. Preparations for the Platinum Jubilee events started soon after I took over as the President in 2008 January. I took special care to involve all the past Presidents in the celebrations, in one way or the other. My colleagues and I were also greatly benefitted by their advice and suggestions.

The Platinum Jubilee celebrations were formally inaugurated by the then Prime Minister Manmohan Singh at IIT Delhi on January 10, 2009. Originally we got the impression that the PM might give an hour for the function. We prepared a tentative schedule on that basis. In addition to myself, I thought it would be appropriate if M.G.K. Menon, the seniormost surviving past President and doyen of Indian science, also spoke in the function. Menon was very pleased when I invited him to do so. We also hoped that the Minister of Science and Technology would participate in the function. In the event, the PMO cut short the programme to last only for half an hour. The final programme involved only welcome by me, the Prime Minister's address and vote of thanks by Surendra Prasad, the Director of IIT Delhi. Later on, we surmised that the duration of the function was reduced on account of the health condition of the PM. In any case, I was deeply embarrassed in relation to the participation of Menon. I did not know how he would react to his removal from the inaugural programme, after I had specifically invited him to be part of the programme. I contacted him over the phone. His response completely disarmed me. He said "such things happen while dealing with the PMO. Don't worry. My participation in the programme is unimportant. The important thing is that they listen to you, the present President" An example of Menon's nobility and generosity!

On January 10, I received the Prime Minister at the entrance of the main building of IITD and escorted him to the auditorium. That was the only time when I was alone with him except for the security staff. His presence was in no way intimidating, in spite of the powerful position he occupied. While escorting him, I told him "Sir, we are delighted that you are with us this morning". He replied, "I am also delighted particularly as I am away for half an hour from the pressures of national affairs!". The inaugural function was an impressive affair. The inaugural events were meant to be an Indian affair with the participation of past Presidents and other national leaders of science. However, it so happened that my friend Guy Dodson, a Foreign Fellow of the Academy, was in India during that period. I was very pleased that he was present during the inaugural event. Kalyani was, of course, by my side during the events.

The inaugural function was followed by the Platinum Jubilee lecture by C.N.R. Rao. A special session on 'Indian Science and the Global Context', which followed, was chaired by R. Chidambaram and M.G.K. Menon was the keynote speaker. The other speakers included senior scientists and middle level workers. Another special session chaired by S. Varadarajan was devoted to presentations by four youngest Fellows of the Academy. The events of the day were wound up with an evening lecture by Kapila Vatsyayan, a doyenne of Indian culture. P.N. Tandon chaired the session. During her talk, she listed the persons who have influenced her, starting with Rabindranath Tagore. The list included Itti Ravi Nambudiri, which greatly surprised me. My uncle (the elder brother of my father), whom I referred to earlier, had the name Itti Ravi Nambudiri. During dinner, Kapila Vatsyayan confirmed that she was indeed referring to my uncle who was a great vedic scholar. I wondered how they communicated with each other as my uncle spoke only Malayalam with perhaps a smattering of Sanskrit! Later on, I came to know that Kapila Vatsyayan had visited him in Kerala and they were in touch with each other.

The special Anniversary meeting was held on the 11th with award lectures by several distinguished scientists. I gave my first Presidential Anniversary lecture on "Back to basics" in which I discussed my work on aggregation involving amino acids and chemical evolution, in addition to outlining our efforts on protein hydration and its consequences. The third day was devoted to a discussion on education involving all the three science Academies, led by N. Mukunda.

The Science Day, February 28, in the Platinum Jubilee Year, with Abdul Kalam as the chief guest was celebrated jointly with IITD. INSA sponsored several scientific meetings during the Jubilee Year. By a happy coincidence, 2009 was the 200th year of the birth of Charles Darwin and the 150th anniversary of the publication of Origin of Species. A special meeting was organized during the Jubilee Year by R. Gadagkar and S.K. Saidapur on Darwinism, in Karnataka University, Dharwad. Another special meeting was on 'Molecular Medicine Based on National Resources and Traditional Knowledge' at NCL Pune, organized by Samir Bhattacharya. I had the pleasure of addressing both the special meetings and giving talks in them. The Platinum Jubilee of INSA almost coincided with that of IASc. At the invitation of D. Balasubramanian, the then President of IASc, I spoke in the inaugural session of the Platinum Jubilee celebrations of IASc. Again, by a happy coincidence, 2009 was the birth centenary year of

Homi Bhabha, a past President of INSA. The birth centenary was celebrated on a grand scale under the leadership of DAE. DAE generously arranged an Academy session as part of the main event. I had the pleasure and privilege of speaking in that session.

Many books, compilations, and reports were produced by INSA during the Platinum Jubilee Year with the active involvement of Fellows. Two of them were special and somewhat unusual. One of them, a book titled "Bright Sparks" was by Arvind Gupta who popularizes science, particularly using toys. The book contains short biographies, with illustrations, of past Indian scientists. The book has since been translated into several Indian languages. Another volume "Science in India: Achievements and Aspirations" edited by H.Y. Mohan Ram and P.N. Tandon contains an authoritative account of the state of modern science in India.

We decided that the concluding session of the Platinum Jubilee celebrations should be held in Kolkata, the original home of INSA and a city with which I have had a special relationship. The main organizers of the meetings were Sushanta Dattagupta, the then Director of IISER Kolkata and Milan Sanyal, the then Director of SINP. They were ably assisted, in fact their efforts were co-ordinated, by Chanchal Dasgupta of the Science College. The concluding meeting was a rather long affair, lasting four days during 7-10 December 2009. The meeting was held in the main auditorium of SINP. In addition to leading Indian scientists, representatives, mostly Presidents, of many sister academies around the world and international organizations also attended the meeting. The meeting turned out to be a star-studded affair. The then minister of Science and Technology, Prithviraj Chavan, himself a trained engineer, attended part of the meeting. Incidentally, I have had interactions with him during my Presidentship of INSA and was impressed by his interest in and involvement with Indian science.

The concluding meeting was inaugurated on the 7th morning by Pratibha Patil, the then President of India. Another notable presence at the inaugural function was that of Gopal Krishna Gandhi, the then Governor of West Bengal. The inaugural function was followed by Keynote addresses by Bruce Alberts, a former President of the US National Academy of Sciences and a great friend of India; Y.T. Lee, the Nobel Laureate; and M.G.K. Menon. Prithviraj Chavan, who spoke at the meeting, felicitated and presented mementos to the guests from abroad. Two major symposia, spread over the first two days, were conducted during the meeting with participation of Indian and foreign scientists. One was on 'Role of International Scientific Organizations and Programmes in the Emerging Global Scenario' and the other one on 'Role of National Academies in Education, Research and Science Policy'

The second day started with a plenary lecture by M.S. Swaminathan. The day's programme also included a non-technical general lecture by the historian Barun De. Apart from a symposium on 'A Collage of Science', the 3rd day was substantially devoted to the formal business of the Anniversary meeting, including my second Anniversary President's address on "Structural Biology of Lectins. The Science and a Slice of History". The half day session on the 10th featured the Blackett Memorial lecture by Lorna Casselton and Award lectures by M.S. Valiathan and by E. Sreedharan, a very well known Indian engineer. Very appropriately, INSA had presented its Viswakarma Award to Sreedharan! As Valiathan noted, the hall was full even on the last day of the symposium. This was due to the vibrance of the academic programme and the eminence of the speakers.

The academic programme was complemented by cultural events and dinners, one of which was in a boat on Ganga. On the 10th evening, Kalyani and I returned from Kolkata with the satisfaction of having concluded the Platinum Jubilee events on a high note.

International relations

Among the three science Academies, international relations are an almost exclusive responsibility of INSA. The most organized and, perhaps the most important, component of this responsibility is adherence to ICSU and its Unions. In 1967, the Government of India formally entrusted this responsibility with INSA. The modalities of this adherence were well set by the time I became the President. We then adhered to ICSU and about 25 of the Unions affiliated to it. As I have described earlier, I have been intimately associated with the activities of two Unions, viz., IUCr and IUPAB. The relation of Indian scientists with each union is supervised and promoted by a National Committee. It was also made sure that proper coordination existed between the National Committee and the corresponding professional association or society. For example, the President of Indian Crystallographic Association is an ex-officio member of the INSA National Committee for IUCr. In fact, the Unions are more in evidence than ICSU itself in the scientific community. My role as President in relation to ICSU and the Unions was only to preserve and strengthen the existing arrangements. In a personal capacity and as Chairman of the appropriate National Committee, I was a frequent participant in Crystallography and Biophysics Congresses.

During my Presidentship of INSA, I attended the General Assembly of ICSU held in Maputo, the capital of Mozambique in October 2008. The meeting was held in Mozambique as part of the international scientific communities' attempt to reach out to Africa. Our Chandrayan-I mission took place when the ICSU General Assembly was on. The Assembly was electrified when I announced this achievement of ours. I have been involved in a few more ICSU meetings and activities, but the involvement has been much less intense than my involvement with IUCr and IUPAB.

One meeting of an ICSU committee that I particularly remember is the one on "Weighted Voting" held in Paris during 7-9, May, 2010. Paris, the city of "Liberty, Equality and Fraternity" and much else, always excited me. This time, Kalyani also accompanied me, particularly as we were planning to proceed from Paris to London to participate in the birth centenary celebrations of Dorothy Hodgkin at the Royal Society, London, on May 12. The deliberations of the meeting itself were somewhat strained and led to a compromise solution. However, we enjoyed our stay in Paris. Kalyani and I together had gone to Paris exactly 40 years ago. I have visited the city in between on work, but coming together again after four decades gave much satisfaction. By the time the Paris meeting was over, the Iceland volcano erupted and there were uncertainties about air travel. Therefore, we had to cancel the London trip and return to India. Rohini Rao of the ICSU Headquarters was of great help in re-arranging our programme.

On the initiative of ICSU, the Committee on Science and Technology for Developing Countries (COSTED) was established around 1970 with Chennai as the headquarters. COSTED had an umbilical cord with INSA. COSTED had a checkered history. From 2005, it functioned under different names, with the help of P. Rama Rao and T. Ramasami. The leadership of the organization was taken up by P.S. Goel in 2008. After some administrative rearrangements, the organization was renamed as Centre for International Co-operation in Science (CICS), towards the end of my Presidentship of INSA. The centre has been involved in management of fellowships for developing countries, participation of Indian scientists in international meetings and a host of other promotional activities.

The World Academy of Sciences (TWAS) is an international organization in which many INSA Fellows are members. INSA has paid particular attention in ensuring participation of Indians in the annual meetings of TWAS by providing financial support. INSA also played a major role in securing substantial government support for the TWAS meeting in Hyderabad in 2010.

In addition to ICSU, INSA has been part of other international organizations and regional groupings. Their roles are much less well defined compared to that of ICSU. In fact, I became aware of the details of their activities only after I became the President of INSA. The prominent among these organizations are the Inter-Academy Panel (IAP) and Inter-Academy Council (IAC). India played a major role in establishing IAP in the mid 1990s. IAC is in effect a creation of IAP. The two organizations substantially work in tandem. Both the organizations have been primarily involved in producing documents and advisories on different important issues. Yet another avenue during my time, was the meetings of the Science Academy Presidents of the G8+5 countries, ahead of the Summit of the Heads of States of the G8+5 countries every year. There has always been considerable overlap in the issues discussed in the IAP, IAC and the G8+5 meetings. Many of the participants were also common. In addition to producing authoritative and useful documents, these meetings helped to promote camaraderie and understanding amongst global leaders of science.

The IAP/IAC and G8+5 meetings involve a great deal of international travel. It is important that the President himself participates in these meetings to generate the necessary impact. I had mixed feelings about travel. By and large, I approached them only as a necessary concomitant of work. The travels became pleasurable when Kalyani also started accompanying me. We never travelled together abroad during 1977-1999. I am a structural biologist and she a material scientist. Therefore we, by and large, attended different meetings. It was also not desirable to leave our daughter alone at home. In 1999, she left home for higher studies. We travelled abroad together for the first time in 1999, after 1977. Kalyani retired as a Director grade Scientist from NAL in 2002. She continued in NAL as an Emeritus Scientist till 2007, after which she stopped working. That was around the same time as I became the President of INSA. All the normal, familial responsibilities were now behind us and we had the resources to pay for the additional expenditure involved in Kalyani's travel. Therefore, we made a wise decision to travel together, as much as possible. Kalyani was with me during most of my international trips as the President of INSA.

The secretariat of IAC is located on the premises of the Royal Netherlands Academy of Arts and Sciences in Amsterdam while TWAS headquarters in Trieste host the Secretariat of IAP. INSA, represented by its President, has been for long periods a member of the Executive Committee of IAP and the Board of IAC. Meetings of the two bodies concurrently took place every year in Amsterdam, in addition to those elsewhere. I have attended three of the Amsterdam meetings, one along with Kalyani. In the first of these meetings, the presence and advice of Goverdhan Mehta helped me in familiarizing myself with the proceedings. I particularly remember the 2009 meeting for personal reasons as well. Our daughter was then studying at SDA Bocconi, Milano. We visited her on way to Amsterdam.

I distinctly remember my participation along with Kalyani in the IAP conference on Biodiversity and General Assembly at Royal Society in London during January 2010. The meeting and the associated events were very well organized. It was also a nostalgic visit for us. We were, of course, comfortably ensconced in the Strand Hotel. The India club, a historical landmark for Indians, was located in the neighbourhood. During our stay in Oxford during the 1960s and 1970s, most of our visits to London used to be concluded at India club with a South Indian dinner. A prominent item in the dining hall was a portrait of V.K. Krishna Menon. One evening during the IAP meeting, we had dinner at the India club, for old-times sake. We were disappointed to see the club in a dilapidated state. Another personal highlight of this visit to London was interaction with our niece Sandhya and her husband Rijesh who had by then settled in England. Although we did not know it then, that visit of 2010 turned out to be our last travel to England.

There is a side story to the IAP General Assembly in London. Many sister academies, including those of Australia and China, wanted me to contest for the Co-Chairmanship of IAP. I agreed to be nominated. Later, I came to know that Mohammed Hassan, longtime Executive Director of TWAS, was also a candidate for the post (he was also elected President of TWAS in 2018). I had no wish to contest against Mohammed. In fact, I felt that he would be a much better Co-Chair than me. However, by that time, the die was cast and I could not have withdrawn from the contest without annoying the Academies which nominated me. Mohammed also knew my predicament. As expected, I lost the contest. The situation was akin, of course at a much lower level, to Adlai Stevenson contesting against Eisenhower, the great war hero, for the President of USA, in the 1950s. Someone asked Stevenson about his losing the election. He is reported to have replied “what else do you expect when you contest against George Washington!”. I met Mohammed last at the TWAS meeting in Hyderabad in 2010. During dinner on the eve of the inaugural function, I spotted Mohamed in the crowd. I tried to attract his attention, but could not do so in the din. I then started moving towards him. Sushanta Duttagupta, who was standing nearby, exclaimed “the Mountain goes to Mohammed!”. Sushanta’s booming voice caught Mohammed’s attention and he came towards me saying “Mohammed comes to Mountain”!

An exciting development for IAC in 2010 was a request by the United Nations Secretary General and the Chair of the Intergovernmental Panel on Climate Change (IPCC) to conduct an independent review of IPCC processes and procedures. The invitation was accepted by the IAC Board. A Review Committee was duly set up for the purpose. Goverdhan Mehta was a member of this Committee. The report, prepared after extensive consultations, was submitted to the UN Secretary General on 30 August 2010. The report was well received by all concerned. Needless to add, the invitation from the UN to prepare such a report enhanced the prestige of IAC.

Our visit to Santiago, Chile to attend a meeting of the Executive Committee of IAP held during 2-5 November 2010, was also memorable. The Latin American ambience is exhilarating. The meeting was very productive and the hospitality enjoyable. The historic landmarks in and around Santiago were also impressive. The journey from Santiago to the next destination (Venice/Trieste) was hectic. We started on November 6 and reached Venice the next day, via Sao Paulo and Frankfurt. We could just make the flight connections at Sao Paulo and Frankfurt with a great deal of running from terminal to terminal. From Venice, we were taken to Hotel Savvoy in Trieste by car.

My programme involved participation in the meeting of the Council of Scientific Advisors of ICGEB on 8 and 9, November and that of the Board of Governors on 11. On the free day in between, we went on a day trip to Venice. Venice of course was very impressive. The meeting of the Council of Scientific Advisors was scientifically very rewarding. That of the Board of Governors was a very officious affair involving representatives of Governments who had stakes in ICGEB. While

I was busy with the meetings, Kalyani had a peaceful time in the pleasant ambience of Trieste. Our hotel overlooked the Adriatic Sea.

I accompanied the new incumbent Krishan Lal to the next meetings of IAP and Networks of Academies held in Washington on March 29-30, 2011, after I relinquished the Presidency of INSA on 31 December, 2010. This was to maintain the continuity of our relationship with IAP and associated organizations. The participation in the meeting provided me with an opportunity to visit the Headquarters of the U.S. National Academy of Sciences and familiarize myself with the workings of the Academy. Kalyani and I used this opportunity to visit her mother and brothers at Baltimore and spend time with my niece Swapna, her husband Amit and their family. Even after the Washington meeting, I continued to be involved with IAP for a couple of years, particularly with regard to reviewing research and other proposals submitted to IAP.

The meetings of the Presidents of the G8+5 countries were somewhat grander affairs. At the end of each meeting, joint statements on a couple of topics are issued after extensive consultations. The statements are presented to the Heads of States of the G8+5 countries. The first G8+5 I attended was the one in Tokyo during 17-18 March, 2008. T.P. Singh, Vice-President in charge of International Affairs, accompanied me. The meeting specifically addressed issues of “Climate change adaptation and the transition to a low carbon society” and “Global Health”. In relation to the former, the problem was how we can achieve sustainable development without causing harm to environment, including climate change. In one of the presentations, I argued that sustainable development is related to sustainable consumption. The advanced countries and prosperous sections of the less advanced countries are consuming much more than what is necessary. Representatives of the advanced countries in the meeting did not accept this argument. They argued that it is not possible to define what is necessary. Nevertheless, the discussions were of a high standard and the statements issued after the meeting were well balanced.

The next G8+5 meeting was in Rome during 26-27 March, 2009 hosted by the Accademia Nazionale dei Lincei (which is in effect the name of the Italian Academy of Sciences). This is one of the oldest academies in the world hallowed by the Fellowship of greats like Galileo. The premises of the Academy is marked by grandeur.

The Rome G8+5 meeting closely followed the 2009 IAP, IAC meetings in Amsterdam. Therefore, Kalyani and I went directly from Amsterdam to Rome. The themes of the Rome meeting were “Climate change and the transformation of energy technologies for a low carbon future” and “International migration: challenges requiring global attention”. At my invitation, V.S. Ramamurthy also attended the meeting, particularly in relation to discussions on energy. The meeting took place soon after the global economic collapse of 2008. The participants were now more receptive to my plea for sustainable consumption. The ambience was somewhat sombre. I recall the then President of the US National Academy of Sciences, Ralph Cicerone, whom I got to know reasonably well, mentioning that Obama was the only ray of hope! Much of the discussions on migration centered around brain drain. Arriving at a joint statement on energy was comparatively easy. Migration was a hotter topic to handle, as it remains today. In the course of the meeting, the organizers arranged an interaction of the participants with the President of Italy.

The third and final G8+5 meeting I attended as the President of INSA was at Ottawa during April 7 and 8, 2010. The topics for consideration at the meeting were "Innovation for Development" and "Health of Women and Children". Mahtab Bamji who has worked extensively to improve the health of women and children and who was then a Vice-President of INSA, also participated in the meeting at my invitation. Discussions on both the topics had a Canadian touch. Much of the deliberations on the first topic were concerned with developmental issues pertaining to Africa and other developing regions. I was pleased to hear the IIT system of India projected as a model for higher education networks in developing countries. The famed Kerala model was mentioned in relation to the health of women and children. The meeting led to two well drafted joint statements. From Ottawa, I went to Toronto where Kalyani had already arrived at the residence of her sister and nephew. The stay in Toronto was pleasant and included a day trip to Niagara.

In addition to involvement with international organizations, INSA has strong bilateral relationship with a large number of sister academies all around the world. The Exchange Programmes with many of them have been extraordinarily useful in establishing contacts and initiating joint projects. INSA has a robust system for managing bilateral relations and I tried to preserve and improve the system. I already mentioned my efforts to update our relations with the Chinese Academy of Sciences. Incidentally, it turned out that a Chinese scientist was for the first time elected as a Foreign Fellow of INSA during my Presidentship. Our updated relationship with the Mainland Academy did not dampen our engagement with the Chinese Academy of Sciences of Taiwan. A memorable visit of ours was to attend the Presidents' Forum organized by the Academy in Taiwan in December 2008. Presidents of many important Academies and their spouses were invited to the meeting. The hospitality we received was overwhelming. President Ma inaugurated the Forum without any frills of Office. The discussions in the Forum were of a high standard. We made use of the visit to interact with Indian students in Taipei as well.

Many important scientists visit INSA. One visit that I particularly remember is of the Nobel Laureate Steven Chu who was then the Secretary of Energy in the Government of the United States, on November 14, 2009. A Secretary in US administration is equivalent to a senior cabinet minister in India. He had come for high level discussions with the Government of India. One day, INSA office got a telephone call from US Embassy informing that Chu would like to visit INSA and enquiring whether we would be happy to receive him. We were delighted and deeply touched. It was remarkable that he thought of INSA even in the middle of his busy schedule involving high level negotiations. We accepted the offer with both hands. I assembled local Fellows of INSA in Delhi, including M.G.K. Menon, a former central Minister, to interact with Chu. Chu spent a couple of hours with us discussing science and other issues. We felt as easy with him, as we would with any other fellow scientist.

The last dignitary I received at INSA as President was Lu Yongxiang, the President of CAS. He was presented the Jawaharlal Nehru Birth Centenary Medal of INSA on December 22, 2010. After receiving the medal, Lu gave the customary lecture. I had already come to know him reasonably well through participation in IAP/IAC and G8+5 meetings. It was a special pleasure for me to have the President of the Chinese Academy at INSA before I relinquished office.

Academies. Low cost, high value institutions

It is estimated that over a hundred thousand scientists, work in India. Those who are Fellows of one or more Science Academies of India could be around 2000. The number of those who aspire to be a Fellow would be much higher. Failure to get elected to Academies often leads to disappointment. Those who get elected to the Academies are by and large excellent scientists, but it cannot be said with certainty that all excellent scientists get elected to Academies. All the same, the Academies are considered to represent the scientific community of India. Academies are generally held in high esteem. Even in the power conscious Delhi, INSA and its office bearers are respected, in spite of its having no real power. Not only the Secretaries and other officers of science departments, but even the offices of the Prime Minister and President of India deal with INSA with great consideration. Furthermore, the effort has been to ensure that the activities of the three Academies benefit the entire community.

For historical reasons, India came to have three science Academies. As mentioned earlier, they now work in tandem. Each one of them performs its primary function of recognition and encouragement of excellence with due diligence, although as in any other human endeavor, occasional mistakes occur. In areas concerned with education and training, the three Academies work together. In most other activities, there is a measure of complementarity among them. In a sense, INSA is the official Academy. It interacts with the Government more than the other two Academies. International relationships are almost exclusively handled by INSA. History of Science is also a part of INSA's mandate. Publications and other academic activities constitute the strength of IASc. The editorial standards maintained by

IASc are very high. The Academy maintains a highly scholastic ambience. The same is true about NASI. Some activities of NASI, such as support to senior scientists and presentation of awards, bear resemblance to those of INSA. NASI also has a publication programme. In my view, the distinctive strength of NASI is in its outreach programme. There is a view that it is desirable to merge the three Academies into one. However, this is not logistically simple. There are some other countries also where more than one science Academy exists. In any case, the three Academies of India now function well with considerable coordination among them and with complementary strengths.

The atmosphere in the head quarters of all the three Academies is informal and homely. Work is carried out efficiently without too much of bureaucratic delays. The autonomy enjoyed by the Academies is partly responsible for these positive features. It is therefore important to fiercely defend the autonomy of the Academies. They should never be treated as part of the Government. The budgets of the Academies are comparatively low. The amount handled by each Academy is comparable to that spent in a large sponsored project. It is also important that the budgets are kept at a level just about adequate to support its activities. Huge sums are likely to bring along with them additional bureaucracy. In fact, academies are generally recognized as low cost, high value institutions.

I have enjoyed working in the Academies. We need to constantly review and improve upon our activities. However, Academies should remain temples of excellence and scholarship, and not become executive arms of any agency. In a broad sense, the role of the Academies is not to execute, but to inspire and guide with humility and without condescension.

14

GOVERNMENT AGENCIES, INSTITUTIONS

There have been proposals for my taking up administrative positions such as Government Secretary, Vice-Chancellor etc. I never encouraged these proposals, not because such positions are not important and prestigious, but accepting them would come in the way of my primary career objective of contributing to building up macromolecular crystallography and related areas in the country. Except for my early sojourns to Oxford, I never left IISc and my lab. In IISc itself, I was deeply involved in administration. Although I did not take up administrative positions elsewhere, I was involved intimately with the work of Government agencies and many scientific and academic institutions. I have already outlined my limited, but intense involvement with ISRO in relation to chemical evolution and origin of life and exobiology. I have had more extensive association with the Science departments of the Government of India and several institutions across the country.

Departments of Science & Technology (DST), Biotechnology (DBT) and Scientific and Industrial Research (DSIR)

The Ministry of Science & Technology is made up of three departments, viz, DST, DBT and DSIR. DSIR is nominally the administrative department of the Council of Scientific and Industrial Research (CSIR), which is always headed by DG CSIR. I have had very close association with DST, DBT and CSIR. I have worked with them in advisory capacities very extensively and also received to different extents, extramural support from all the three of them.

My association with DST was perhaps the closest among the three. DST was established in 1971, which I believe made a substantial difference to Indian science. DST came to be recognised as the most important government agency concerned with science and technology. I have had the privilege of knowing almost all the Secretaries of DST. For all intents and purposes, Arcot Ramachandran was the first Secretary of DST. He was an upright man with great stature. A. Ramachandran was followed by M.G.K. Menon, S. Varadarajan and Yash Pal, all illustrious leaders of Indian science. V.R. Gowarikar took over the mantle from Yash Pal. I knew him, but not very intimately. Gowarikar was succeeded by P. Rama Rao, again a distinguished leader of science, senior to me. The next Secretary was V.S. Ramamurthy, my contemporary and friend. Ramamurthy had a long innings spanning more than a decade. The next Secretary was T. Ramasami whom I have known very closely from the days when he joined as a scientist in the Central Leather Research Institute, Chennai. By the time Ramasami retired, I had begun to withdraw from formal responsibilities.

As I explained earlier, myself and the areas which I helped to initiate and develop, are to a substantial extent, products of DST. I have also earlier touched upon my involvement with the INSPIRE programme. The number of DST Committees of which I have been Chairman or member is far too large to be enumerated. There are two efforts in which I have been involved on a long term basis. One is the work involving Science and Engineering Research Council (SERC) along with the Project Advisory Committee (PAC) system. The other is the operation of Fund for Improvement of S&T infrastructure in universities and higher educational institutions (FIST).

During nearly four decades of its existence, DST-SERC was the backbone of extramural research support in the country. SERC was the jewel in DST's crown and was led successively by P.J. Lavakare, V. Rao Aiyagari and B. Hari Gopal. Another important officer in its SERC section, who died prematurely was R.C. Srivastava. As far as project-based research support is concerned, SERC acted through a number of PACs, each concerned with a subject area. Decisions on projects with outlays below a certain prescribed amount were taken at the PAC level itself. SERC endorsed the decisions of the PACs on smaller projects while it took the final decisions on larger projects on the basis of the recommendation of the PACs. The decision making processes were rigorous, but flexible. The same was true about the operation of the projects. Most importantly, the system was managed by a wonderful set of officers who exhibited a high level of sensitivity to the problems of scientists, total commitment to work at hand and great competence. The general approach involved funding projects adequately, but not extravagantly. Quite apart from the money involved, receipt of a SERC project used to be considered as a badge of honour.

I have been a member of SERC and concurrently Chairman of the PAC concerned with biochemistry, biophysics, molecular biology etc. during 2005-2012. We maintained a highly interactive relationship between investigators and the PAC. In many PACs, including the one chaired by me, most investigators used to be asked to present their proposals before the committee and other investigators gathered at that time. A project proposal was rarely turned down without providing adequate opportunity to the investigator to present his/her case. Budgetary details also used to be finalized on the basis of discussions with the investigator. The presentations before the PAC and the subsequent discussions were often made use of as a mentoring exercise.

SERC not only considered project proposals, but also discussed general policy issues. These discussions often led to new initiatives. During my tenure as a member of SERC, a major topic of discussion was in relation to a new mechanism for extra mural funding. I was an active participant in the deliberations, partly because I was the Vice-President and then the President of INSA during most of this period. I was also perhaps the seniormost member of SERC.

The issue of a new mechanism for extramural funding was mooted by SAC-PM in 2005. By then, I was actively involved with not only DST, but also DBT and CSIR. Therefore, I was inevitably drawn into the discussion on the matter. As indicated earlier, my position in INSA also added an edge to my involvement. As I have mentioned in a *Current Science* article (*Curr. Sci.* **114**, 1810-1811, 2018) "There was real or perceived thrust towards setting up a huge monolithic organization combining the extramural mechanisms of all or many granting agencies. There was considerable resistance to and apprehension about creating such a behemoth. Many of us felt that the setting up of such a powerful and all-embracing organization is not conducive to the healthy development of science in the country. Plurality of sources of research funding is absolutely essential. Instead, many of us felt that it would be desirable to have autonomous extramural wings to different granting agencies. In any case, eventually the idea of an all-embracing outfit was shelved". The report of the Steering Committee for Science and Technology in the Eleventh Five Year Plan (2007) advocated the setting up of an autonomous body in addition to the existing ministerial mechanism for funding. Eventually the proposal boiled down effectively to replacing SERC by a new body called Science and Engineering Research Board (SERB). The necessary legislation was passed in Parliament in 2008. Many of us were not enthusiastic about the replacement of SERC by SERB as seen from the quotation, given below, by R. Ramachandran (***Frontline***, 28 February–13 March 2009). 'Noted biologist M. Vijayan, however, preferred to reserve his comments on the SERB. "Its functioning is yet to be seen. Among the systems we have had so far, the SERC and its system of PAC (Project Advisory Committee) certainly worked reasonably well and achieved a healthy growth and spread of basic competitive research. Admittedly, its functioning could be improved; I am not sure whether we need an altogether new body", he said.' A major concern of many of us was how to map the positive features of SERC onto SERB. We did everything possible, inside and outside SERC, to ensure that.

In the event, in my opinion, SERB turned out to be much less effective than SERC, for reasons that I need not go into here. Fortunately, SERB has substantially retained the officer corps of SERC. The officers of SERC have been one of the mainstays of the organization. In addition to serving the scientific community as well as they could, these officers ensured the continuity of the operations of SERC and SERB. The need now is to fully restore the positive features of SERC to SERB and to improve upon them.

I have been involved with the FIST programme from its very inception in 2000. During the first few years, I was a member of the Subject Expert Committee on Life Sciences, chaired by Girijesh Govil. I became the Chairman of the Committee in 2006 and continued in that position till 2015. I was also a member of Apex Committee of the FIST programme called FISTAB, chaired by S.K. Joshi during that period.

PAC and FIST presented contrasting situations. In the PAC one dealt with excellent projects by India's best scientists. Each PAC was concerned with a comparatively restricted area. For example, the PAC I chaired, dealt with biochemistry, biophysics and molecular biology. I knew all the PAC members and many of the investigators personally. FIST was meant to provide infrastructural support to all deserving departments in the country. In effect, one came face to face with the Indian reality. Hundreds of proposals, including those chosen for presentation, were dealt with in each sitting. The quality of the departments varied very widely. That was reflected in the quantum of assistance provided as well. The quantum varied between Rs. 25 lakhs to Rs. 9 crores. Mentoring was more relevant in the FIST programme than in the PAC operations. I encouraged, criticized, cajoled and admired the investigators as required. Most people accepted our suggestions gracefully and were grateful to us. FIST considered departmental proposals. Often differences cropped up among the faculty members of the department as to what requirements should be projected. I often intervened to settle the differences. The person who helped me most in the committee was Alok Bhattacharya of the Jawaharlal Nehru University. He did the same thing in the DBT Task Force on Bioinformatics. In both the committees Alok succeeded me as Chairman. The rapport between Alok and myself was almost perfect.

The FIST Committee consisted of scientists from all areas of Life Sciences, including distinguished medical practitioners. I got to know most of them very well. The Committee functioned almost as one family. One of the members, perhaps the youngest among us, was Padma Srivastava, a distinguished neurologist at AIIMS. Many, including N.R. Jagannathan, contributed to maintaining the family-like atmosphere.

Central to FIST was Amalesh Mukhopadhyay who was the DST officer in charge of the programme. Mukho, as we called him, was highly competent and committed. His grasp of the overall thrust as well as the details of the programme was impressive. Mukho had a phenomenal memory and he could instantaneously recall the positive and negative aspects of the implementation of almost every project. I used to often describe him as Chitragupta, whom no sinner can get past! Even after he got involved with INSPIRE, he continued to look after FIST with the help of junior officers whom he had trained.

I have attended many public functions associated with DST. A couple of them stand out in my mind. One was the Foundation Day lecture by A. Ramachandran in early May, 2008. I had become the President of INSA a few months earlier. A substantial part of the lecture was addressed to me in relation to the role INSA can play in Indian Science. Another function that I remember was held in May, 2011, to mark the 40th anniversary of the Foundation of DST. The meeting was addressed by M.G.K. Menon, S. Varadarajan, Yash Pal and V.S. Ramamurthy, all former Secretaries of DST. P.J. Lavakare and Rao Aiyagari, the past and then Heads of SERC, and myself as the seniormost member of the SERC, also addressed the gathering. During that function, we lived through the illustrious history of DST.

I have been closely associated with DBT as well. The National Biotechnology Board (NBTB) was established in DST in 1982 under the leadership of S. Ramachandran. Ramachandran became the first Secretary of DBT when it was established in 1986. Many have the uneasy feeling that he did not receive the recognition he deserved. Ramachandran was succeeded by C.R. Bhatia, an upright, erudite scientist form BARC. After his short stint, Manju Sharma became the Secretary of DBT. She has been a many splendoured leader and took DBT to great heights. She was succeeded by M.K. Bhan, another effective leader who introduced many new projects. After his retirement, K. VijayRaghavan, a highly acclaimed scientist, became the Secretary. Most recently he was succeeded by Renu Swarup who has been an officer at DBT for a long time.

As indicated earlier, my association with DBT started when it was in its incipient stage as NBTB. Much of my early interactions with DBT was on behalf of IISc. These interactions have been described in some detail in the chapter on my association with IISc. Most of the efforts centred around Manju Sharma. I got involved in many other activities of DBT also during her Secretaryship. This involvement continued till the early phase of VijayRaghavan's tenure, when I withdrew from many activities on account of ill health. Soon after Bhan took over as Secretary, he invited me to chair the Bioinformatics Task Force, a position I held until 2013. I have, of course, worked as a member of this Task Force earlier, but chairmanship was a different ball game which involved presiding over a large network. My efforts in this role have again been described in an earlier chapter.

I have worked in several DBT committees including the Task Forces on Infrastructure and Centres of Excellence; Human Genetics and Genome Analysis; and Infectious Disease Biology. I orchestrated a national effort on the structural genomics of microbial pathogens through DBT, with the blessings of the PSA. I took particular interest in promoting TB research. In these efforts, the others involved included Shyam Agarwal, T. Jacob John, M.R.S. Rao, Anil Tyagi, Seyed Hasnain, Nirmal Ganguly, V.M. Katoch, Akilesh Tyagi and many other distinguished colleagues. India did not for a long time take to genome sequencing for a variety of reasons. Many of us were concerned about it and caused DBT to mount an initiative. Through extensive consultation, *Mycobacterium indicus pranii*, an indigenous mycobacterium, was chosen for genomic sequencing. The work was carried out by the two Tyagis and Seyed. Since then, many genomes have been sequenced in India.

Among the DBT supported autonomous institutions, I have been involved deeply with NII, substantially with CDFD and to an extent with NCCS. I have been associated with the Rajiv Gandhi Centre for Biotechnology (RGCB), Thiruvananthapuram from its inception. Eventually, RGCB came under the DBT umbrella. Successive Secretaries and officers of DBT did the favour of involving me in discussions on policy and organizational matters. I recall my participation in the early discussions organized by Bhan on the Faridabad cluster involving Regional Centre for Biotechnology (RCB) and Translational Health Science and Technology Institute (THSIT). I wistfully remember my role in formulating the procedure for extension of the services of scientists in DBT-supported institutions. I was the chairman of the concerned committee. Retirement age in the university centres has been raised to 65 years, but it remained 60 in most institutions supported by Ministries other than the MHRD. In DBT-supported institutions, we developed an approach which consisted of extending the services of scientists who performed reasonably well by two years and those of high performers by longer periods. I have also been involved in implementing this overall policy. I understand that unfortunately this system is not in vogue now.

DBT has made a real difference to Indian science. This has been achieved primarily through extramural programmes, although the impact would have been greater, had the delivery been more efficient. DBT is the youngest among the three outfits under the Ministry of Science and Technology and the systems associated with it are yet to fully mature. An impression has recently gained ground that the emphasis of DBT is shifting from extramural research to organizations and institutions. I hope that this impression is wrong. The primacy of extramural support in the mandate of DBT shuld be maintained and strengthened.

CSIR is a great organization of pre-independence vintage and has served the community for more than 75 years. Almost all Indian scientists would have been touched in one way or the other by CSIR at some stage in their career. I certainly have been. My association with CSIR became closer from 1984 when S. Varadarajan was the DG CSIR. Varadarajan was succeeded by A.P. Mitra, S.K. Joshi, Ramesh Mashelkar, Samir Brahmachari, Girish Sahni and Shekhar Mande, in that order. I have had close relationship with all of them. As indicated earlier, Varadarajan was a decisive influence in my career. Even after he retired from CSIR, I continued to be involved with A.P. Mitra, particularly in ADCOS. S.K. Joshi was my favourite teacher in Allahabad. He was also a predecessor of mine as INSA President. I continued the work with him in many capacities. Mashelkar is my contemporary. I have already referred to our work together in INSA. He always remained a good friend. I have interacted very closely with Samir from his student days when I have taught him and also supervised a fraction of his doctoral work. My closest association with CSIR was when he was the DG. By the time Girish became the DG, I had begun to withdraw from many activities, on account of bad health. He is a former student of IISc and I have interacted closely with him when he was the Director of IMTECH. Shekhar is a former Ph.D. student of mine and I have been associated with many stages in his career. He has been dear to all of us in the family. Thus, my involvement with CSIR was tinged with close personal relationships.

Apart from working in the Apex Bodies of CSIR for a period of time, I have been all along involved, like many other scientists, in different activities of CSIR and its constituent laboratories. For instance, I have worked in the Physical Research Committee and the Research Committee concerned with Modern Biology, at different times. These committees are responsible for advising on extramural grants. The research councils I worked on include those of CLRI, IICB, CDRI, CCMB and Central Food Technology Research Institute (CFTRI), Mysuru. I have been a frequent participant in the appointments, assessments and promotion processes of many institutions. I also chaired committees at the headquarters for distribution of funds among different CSIR laboratories, network programme etc. and participated in discussions on policy formulations, preparations of plan proposals etc.

I was a member of the Governing Body of CSIR and the CSIR Society during 2008-2013. That period coincided with Samir's stewardship of CSIR. Samir was a very effective DG and achieved much during his tenure. His achievements included the streamlining of the assessment and promotion system. Measures were also taken to ensure that good performers continued to work years beyond formal retirement (these measures have since been undone). I have been with him in most of his endeavours. During his period, I participated in the selection of Directors of many CSIR laboratories. I chaired the Finance Committee of CSIR. The breadth and depth of my involvement with CSIR during this period were enormous.

The Academy of Scientific and Innovative Research (AcSIR) was established as a CSIR University, during this period through an act of Parliament. When the bill was moved in the Parliament by Vilasrao Deshmukh, the then Minister in charge of Science and Technology. Murli Manohar Joshi raised some objections. A meeting of senior scientists was arranged to resolve the issues. Deshmukh's political acumen was on display in that meeting. He invited Joshi to co-chair the meeting with him. He kept a low profile throughout and let Joshi conduct the meeting. Joshi, himself a scientist, knew all the participants well. At the end of the meeting, Joshi accorded his concurrence for the establishment of AcSIR. It was clear that Deshmukh was more interested in getting the concurrence of Joshi than asserting his position.

The first formal meeting in relation to the establishment the Academy took place in a small room in the CSIR headquarters. The participants of the meeting were Samir, Sreekumar Banerjee, the then Chairman of the Atomic Energy Commission, K. Radhakrishnan, the then Chairman of Space Commission, and myself as the President of INSA. It is from this small beginning that AcSIR grew into what it is today.

The CSIR Governing Body and Society were star-studded bodies. The members included government secretaries, senior scientists, captains of industry and eminent persons from different walks of life. This was particularly true about the Society, the meetings of which were chaired by the Prime Minister. I was by then among the senior scientists of the country and often had the opportunity of opening the discussions, after the remarks of the PM and the presentation by the DG. The then Prime Minister Manmohan Singh radiated peace and good will. After the meeting, he always went around and shook hands with all the participants of the meeting. In the last meeting I attended, Mamohan Singh told me “Nice to see you again, Professor Vijayan”. I was flattered that he remembered me even though I have met him only a very few times.

I cherish my long association with CSIR, including with its officers. The organization has a wonderful officer corps. The officer with whom I interacted most was Sudeep Kumar. I deem it a privilege to have worked closely with the organization. The range of activities of CSIR laboratories is truly breathtaking. The laboratories straddle the strategic and the non-strategic sectors. The contributions of CSIR to the nation are seldom fully appreciated. CSIR is a highly under-rated organization. It often comes under pressure from Government and other quarters. Partly on account of the resulting financial crunch, the extramural programme of CSIR is now a pale shadow of what it was originally. We as a community need to do everything possible to support CSIR and to bring back its extramural programme to its old glory.

Institutions

Like any other senior scientist, I have interacted with scores of scientific institutions across the country. I have also given a large number of named and foundation day lectures in most of them. It is difficult to cogently summarise my association with different scientific institutions in India. An attempt is made here to deal with these institutions largely in a regionwise manner.

Chennai

Next to IISc, my association was the closest with Madras University, particularly the Department of Crystallography and Biophysics established by GNR. During our student days, that department was the Mecca of Crystallography and Biophysics. After the departure of GNR and the change in the ambience of the University, the department began to lose its sheen. It was R. Srinivasan who held the fort during this difficult strategic period. Kalyani and I grew close to his family. Our intimacy extended to his brother Kalyanasundaram and his wife P.U. Indira. I have had very close relationships with persons associated with the department. P.K. Ponnuswami was one among them. He has had an interesting career and held important positions including the Vice-Chancellorships of Madras University and Madurai Kamaraj University. I vividly remember S. Parthasarathy, an international authority on crystallographic statistics (probably second only to A.J.C. Wilson!). He was deeply religious and always sported a *namam* (Iyengar's tilak). At the same time, I am told that he took special interest in training students belonging to socially disadvantaged classes. Vasantha Pattabhi, who initiated macromolecular crystallography studies in Madras University, has been a personal friend. So has been N. Yathindra who led the department with distinction for several years. I have also been personally close to the next generation of faculty members like D. Velmurugan, M.N. Ponnuswamy and N. Gautham. The Department is now led by Karthe Ponnuraj, a scientist of considerable competence. Among the new faculty members, I got to know K. Gunasekaran reasonably well.

Many of us were very keen on supporting and helping the Madras department, particularly as it was passing through difficult times. We did all that we could in relation to support from the UGC special assistance programme, FIST programme etc. One major issue was appointment of new faculty. With retirements, the faculty strength of the department dwindled to a perilously low level. I used to bring this problem to the attention of successive Vice-Chancellors of the University. They promised action, but nothing happened, probably on account of the constraints under which they worked. Eventually, I wrote a strong article in ***The Hindu*** on the subject. That probably had some effect. At the inaugural function of a subsequent international symposium organized by Velmurugan (he organized such symposia periodically), the then vice-Chancellor of the University and I were on the dais. On my raising the issue, he promised that he will take action soon. I retorted that I have heard such promises earlier too. The Vice-Chancellor replied that this time the promise was for real. He kept his word. Four new faculty members were appointed in the department soon afterwards.

Another institution in Chennai I was associated with was CSIR-CLRI. I was a member of the Research Council (RC) of the laboratory for three years from 1984 to 1987. The other members of the RC, with whom I grew close include L.K. Ramachandran of Hyderabad and S. Ranganthan, then at IIT Kanpur. Since then, I have visited CLRI often on different occasions. After the Triple

Helix auditorium was built, CLRI also became a favoured destination for symposia and conferences. The person in CLRI I knew best was, of course, T. Ramasami, who served the organization with great distinction for a number of years, until he moved to New Delhi as Secretary, DST. As I mentioned on a ceremonial occasion, Ramasami was a gift of CLRI to the nation. I also had a reasonable level of interaction with IIT Madras. In particular, I was involved along with Joe Thomas, in the early development of the Department of Biotechnology at IITM. Our former student N. Manoj is now a faculty member in the department.

Kolkata

Kolkata is a city in which I have had close associations with many institutions. In addition, I developed an emotional attachment to the City of Joy. Colleagues in Kolkata also reciprocated my affection in ample measure. They treated me as one amongst them. Once J.J. Ghosh, the celebrated biochemistry professor of Calcutta University, remarked that Vijayan would have become a full Kolkatan if only he also ate fish! I recall a function at IICB to felicitate Raman Poddar and S.N. Chatterjee, probably when they turned 70. It was a function which had a distinct Calcutta flavor. B.K. Bachhawat, another distinguished scientist with a strong Kolkata connection, was scheduled to chair the function. He had to leave the meeting before the function started on urgent business. I was honoured to take up the role of the Chairman, in his absence. I took it also as a recognition of my close connection with Kolkata. I always felt at home in Kolkata and among Kolkatans.

Perhaps the institution in Kolkata with which I have had the closest association is CSIR-IICB, located at Jadavpur. I was a member of its RC during 1988-1991. Obaid Siddiqui chaired the RC which was made up of many distinguished scientists. I was the youngest member of the RC. After a long gap, I returned to the RC of IICB during 2010-2015 as the Chairman. I was then the oldest member or among the older members of the RC. During these two stints and in between them, I have been in regular touch with IICB. During my first stint, S.C. Pakrashi was the Director of the Institute. In addition to being an eminent scientist, he was also what the British call ‘a jolly good fellow’. Pakrashi was succeeded by Amar Bhaduri and Jyothirmoy Das, both close friends of mine. They presented a study in contrast. Amar was gentle, soft-spoken and noncontroversial. Jyothirmoy was intense, excitable and somewhat controversial. Both were dear to me. The next Director was Samir Bhattacharya, again a personal friend of mine. His permanent scientific base has been Vishwa Bharathi. I have interacted with him in INSA work as well. The Director throughout my second stint was Siddhartha Roy whom I have watched growing up in the Bose Institute. I have had so many close friends in IICB that it is difficult to mention all of them. A particularly close friend has been Motilal Maiti with whom, among other things, I worked in IBS. My former student Siddhartha Roy (junior) joined as a faculty member in IICB when I was still associated with the Institute.

Indian Association for the Cultivation of Science (IACS), the cradle of much of Indian science and certainly crystallography, is located next to IICB (not its original location). I have had interactions with IACS as well. One of the crystallographers of IACS, with whom I worked closely was S.P. Sengupta. Among the recent Directors, I have interacted closely with Kankan Bhattacharyya and have known the current incumbent Santanu Bhattacharya when he was at IISc. Among the named lectures, I had particular pleasure in giving the K. Banerjee lecture at IACS. I deem it a great honour to have been conferred the Honorary Fellowship of the Indian Association for Cultivation of Science in 2008. My association with the neighbouring Jadavpur University was not very extensive. Whenever in IICB, my stay was almost always in the CSIR Guest House in the neighbourhood of Rabindra Sarobar. I developed good rapport with the employees and felt at home in the Guest House. Occasionally the stay was in the well-endowed Ramakrishna Mission International Guest House at Golpark as well.

My association with SINP has also been long and extensive. The first person from the Institute whom I came to know even when I was a student was N.N. Saha. Despite the age difference, I grew close to him. He is the one who founded the Department of Crystallography and Molecular Biology at SINP. He had the foresight to realize the relation between the two areas, fairly early on. The last time we were together was in Beijing in 1986 to attend the meeting I had already referred to. We returned together from Beijing to Kolkata and at the Kolkata airport he ascertained that someone from SINP was present to receive me. I was scheduled to give a lecture at SINP the next day. While taking leave of me at the airport, he said he would probably not be able to come for the lecture, if it rained heavily. That was the last I saw N.N. Saha. He had a heart attack the next day and passed away.

My continuous association with SINP was primarily through Jiban Dattagupta and his colleagues. Jiban was among the early leaders of macromolecular crystallography in India. I have already described our association and joint activities. I count Bikash Sinha, who was the Director of SINP for a long time, among my friends. Bikash, with an aristocratic bearing, was an outstanding leader. His successor was Milan Sanyal whom I knew very well. I have already described his contributions to the organization of the concluding meeting of the Platinum Jubilee celebrations of INSA. I have interacted with him on other occasions as well, particularly in relation to synchrotron facilities. I have many friends among the faculty of SINP, including my former student Rahul Banerjee. Chandrima, wife of my former student Siddhartha Roy, joined SINP much later. The wonderful guest house of SINP has been a favorite of mine.

SINP is located in Salt Lake. Another institution in the same area is S.N. Bose National

Centre for Basic Sciences. I had frequent interactions with the S.N. Bose Centre as well. I knew slightly the Founder Director of the centre, Chanchal Majumdar. The first Director I knew well was Sushanta Dattagupta. My interactions with him continued even after he moved to IISER, Kolkata. I have already outlined his contributions to the concluding meeting of INSA Platinum Jubilee. Sushanta had unbounded energy and a bubbly personality. Sushanta was succeeded by Arup Raychaudhuri who had his early career at IISc. I have always been fond of Arup and had continuous association with him.

A great institution in Kolkata founded by J.C. Bose is the Bose Institute. Its historic main campus is located at the Acharya Prafulla Chandra Road. It has a second campus in Salt Lake as well. I have frequented both of them. I have worked in committees concerned with the organization of the Institute. I have known well Directors of the Institute like P.K. Ray and B. B. Biswas. Parul Chakrabarti is an old friend from the Institute. Her students Joyoti Basu and Manikunthala Kundu are now senior scientists. One of the Bose Institute scientists in whose appointment I was involved is Gautam Basu. The scientists closest to me at the Institute have been Bhabhatarak (Bablu) Bhattacharya and Siddhartha Roy. Siddharatha moved to IICB as Director, but came back to the Bose Institute as its Acting Director.

I grew close to the Department of Biophysics, Molecular Biology and Genetics at Rajabazar Science College, primarily on account my association with Raman Poddar who nurtured the department. Despite the age difference, I had perfect rapport with him. He occupied important positions including the Vice-Chancellorship of Calcutta University. He was also an elected member of Rajya Sabha. These positions sat lightly on him. His commitment to the Department and to science in general was commendable. I also grew close to other faculty members of the Department, like Chanchal Dasgupta and Ashok Thakur. Chanchal, a dear friend, has been of much help in my efforts in INSA. Ashok went on to occupy many high positions in the University sector in Kolkata.

Dhrubajyoti Chattopadhyay was a faculty member of the Calcutta University, whom I came to know well. For a few years, he was the pro Vice-Chancellor of the University. Towards the end of 2010, I got a call from Dhruba asking me to attend the convocation of the Calcutta University that year. The convocation was scheduled for a day after an INSA meeting at Thiruvananthapuram. It was difficult to wind up the meeting in far South and reach Kolkata the next day. However, my respect for the Calcutta University and closeness to Dhruba, persuaded me to arrange to attend the convocation. I came to Bengaluru by a night flight from Thiruvananthapuram and left for Kolkata by the early morning flight the next day. The trouble was well worth it. At the convocation, I was awarded the Sri Devaprasad Sarvadhikari Medal of the University. The first recipient of the Medal was P.C. Ray and the second, C.V. Raman. All the subsequent awardees have been great scientists. I felt greatly honoured on receiving the medal.

There is an interesting side story to that Kolkata visit. I was joined in the morning flight to Kolkata by U.R. Ananthamurthy, the well known literary figure and activist. That year, Calcutta University had instituted a Tagore Medal to commemorate the 150th birth anniversary of Rabindranath Tagore. Ananthamurthy was the recipient of the medal. We were together during our entire stay in Kolkata and on the return journey. Interacting with him was a great experience. That was the beginning of a short but fruitful association with him.

I have not had any institutional association with the Indian Statistical Institute (ISI), Kolkata. However, I have interacted on several occasions with the distinguished geneticist Partha Majumder who spent most of his career at ISI. He went on to establish the National Institute of Biomedical Genomics at Kalyani. Currently, he is the President of IASc. I admire Partha as an upright person, splendid human being and outstanding scientist.

I have been involved with many conferences, symposia, seminars etc. in Kolkata. The one which was very different from any other, was the seminar on J.D. Bernal, Linus Pauling, Joseph Needham and Federic Joliot Curie, organized jointly by the Jadavpur University and IACS in April, 2002. The dates of the meeting roughly coincided with the birth centenary of all the four. They were not only distinguished scientists but were also deeply involved with societal issues. I was invited to the meeting, presumably because I am a scientific descendant of Bernal through Dorothy Hodgkin. My close association with Kolkata could also have weighed in. Kankan Bhattacharyya was my main contact person. I was a guest in the inaugural function and also delivered the main talk on Bernal. The chief guest in the inaugural function was the legendary Jyoti Basu. He had worked with Bernal in England in the 1930s. I was seated next to Jyoti Basu on the dais in the inaugural function. Near him, I felt like a boy. I had turned 60 and my colleagues and students had organized an international symposium to mark the occasion, a few months earlier. I was then wondering if I should slow down my activities. The proximity to Jyoti Basu, who was active and spritely, also well into his 80s, helped me to dispel all thoughts of slowing down. After the inaugural function I had a pleasant conversation with Jyoti Basu.

Delhi

Next to Bengaluru, the city in which I spent most time during my independent career was New Delhi. The National Institute of Immunology (NII) was the institution with which I had the strongest association. NII was established in the 1980s with G.P. Talwar as the Founder Director. It was Talwar's creation, with of course help from many others. My association with NII started when he was the Director. It became stronger when Sandip Basu, a personal friend, became the Director in 1991. He had a long innings as Director till 2005. He was followed by A. Surolia and Chandrima Shaha in that order. Surolia has been a long term collaborator. I have watched with admiration, the growth of Chandrima to eminence. I was a member of the Scientific Advisory Committee of NII from 1992 to 2015 and Chairman of the Committee for twelve long years from 2003 to 2015. Towards the end of this period, I was seriously ill, but continued until Chandrima retired as the Director. Chandrima was recently elected as President of INSA. I was also a member of the Governing Body of NII from 2001 to 2013. I was deeply involved with the affairs of NII for more than two decades.

My closest colleague at NII was my former student Dinakar Salunke who rose to become the Deputy Director of the Institute. He then moved on to higher positions in other institutions. By that time, Bichitra Biswal, another former student of mine, had already been appointed at NII. I had close interactions with Bichitra as well. I have had many friends in NII. They include Satyajit Rath, Vineeta Bal and Debasisa Mohanty, a former student of Manju Bansal. The Scientific Advisory Committee of NII has always been star studded. I already knew most of its members closely. One person with whom my interactions started through work in the Scientific Advisory Committee was Nirmal Ganguly, a person with encyclopedic knowledge. Nirmal is a splendid human being. Among other things, he served for a number of years as the Director General of ICMR with great distinction. Nirmal and I became close friends.

The first job offer I received was from R.K. Mishra, the then Head of the Department of Biophysics at AIIMS, New Delhi, in early 1968. I was then settling down as a post-doctoral fellow in Dorothy Hodgkin's laboratory at Oxford. Naturally, I did not accept the offer. Over the years, I got to know R.K. Mishra reasonably well. My association with AIIMS grew stronger after Tej Pal moved to AIIMS in the early 1980s. Since then, he has been the fulcrum of my relationship with AIIMS. He eventually became the Head of Biophysics and built a vibrant group in structural biology. I have been close to his students as well. I particularly recall two of them, Punit Kaur and Sujata Sharma, who remained as faculty members in the department. Punit has a warm personality. I have been very fond of her. My interactions with AIIMS thickened when N.R. Jagannathan joined the Institute. Still later, I got to know Padma Srivastava, the well known neurologist. I have had many friends at AIIMS. One of them is Indira Nath, a well known scientist with international reputation. I have worked with her in several capacities.

It is almost impossible for an Indian scientist to have no association with Jawaharlal Nehru University (JNU) and Delhi University. I knew P.N. Srivastava, a distinguished scientist and former Vice-Chancellor of JNU, reasonably well, although he was much senior to me. The persons from JNU with whom I have had the longest association are Asis Datta and Kasturi Datta. Asis also worked as the Vice-Chancellor of the University. On retirement from JNU, Asis founded the National Centre for Plant Genomics Research. I was involved with that Centre as well. Asis, Sandip Basu and I have worked together on many occasions and we are personally close to one another. I have already referred to Alok Bhattacharya of JNU. I also interacted with Indira Ghosh, a former student of MBU, after she moved to JNU. The other colleagues in JNU with whom I had close relations include Rajendra Prasad, Sudhir Sapori, R. Madhubala and Sudha Kaushik. Two of Tej Pal's students (my grand students), S. Gourinath and Ajay K Saxena, became faculty members at JNU. I know them well, particularly Gourinath.

I am familiar with the Main Campus as well as the South Campus of the Delhi University. My association with the South Campus has been stronger and dates back to the time when B.K. Bachhawat established the Biochemistry Department in the 1970s. U.N. Singh established the Department of Biophysics at nearly the same time. Many more science departments came up and the South Campus became a hub of high level of scientific research in Delhi. My friends in the South Campus include Deepak Pental, Akhilesh Tyagi, Anil Tyagi, Jitendra Khurana and B.K. Thelma. Some of them have already been referred to in the narrative earlier. At least three of them have occupied high administrative positions but their research bases continued to be the South Campus. The scientist in the North Campus whom we know well is Vani Brahmachari of the Dr. Ambedkar Center for Biomedical Research.

IIT Delhi has already appeared in this narrative in relation to the Technology Development Mission and the Platinum Jubilee celebration of INSA. The participating department in the Mission was the Department of Bioengineering and Biotechnology. There was a felt need for a regular biological sciences outfit in the IIT. Eventually, the Kusuma School of Biological Sciences was established in 2008. The effort was supervised by a National Committee co-chaired by Surendra Prasad, the then Director, and myself. I have been deeply involved in the early development of the School. The work involved in establishing and nurturing the School was led by B. Jayaram. I have interacted with Jayaram in different ways and I admire him greatly.

The Centre for Biochemical Technology (CBT) was established by CSIR in Delhi in 1977 with the main intention of facilitating supply of biochemicals to Indian institutions. CBT was a comparatively low profile institution. The situation changed dramatically after Samir Brahmachari took over its Directorship. He revamped the institution and rechristened it as Institute of Genomics and Integrative Biology (IGIB). He remained as its Director for 10 years before he became DG CSIR. During this period, he transformed the Institute into a vibrant centre of genomic research. I have been closely associated with the Institute during this period. Among other things, I recall participating in the foundation stone laying ceremony of the new IGIB building. Samir always introduced me during this period as well as when he was DG CSIR as his teacher. That gave me the exalted position of a Rajaguru! I have had many friends in IGIB. I now have a grand student, Bhupesh Taneja (student of Shekhar Mande) in IGIB.

My association with ICGEB was during the period when Virander Chauhan was the Director of the New Delhi laboratory. Macromolecular crystallography was initiated in the laboratory by Amit Sharma. Dinakar Salunke succeeded Chauhan. The highlight of my association with ICGEB was the membership of the Council of Scientific Advisors for three years (2009-2011). The Council met in successive years in New Delhi, Trieste and Cape Town, the three locations at which ICGEB has laboratories. The meetings were illuminating. While working on the Council, I got to know Richard Roberts, the Nobel Laureate. I also renewed my acquaintance with Ananda Chakrabarty, the well known American scientist of Indian origin. I have had cordial relations with Ananda.

I have already referred to my participation in the discussion on the establishment of RCB and THSTI. Dinakar was the first Executive Director of RCB. After a few years, he moved to ICGEB. By the time RCB became functional, my mobility was impaired. Still, I visited the Centre once. Happily, three of my descendants, viz, Deepak Nair, Deepti Jain (grand students) and Prem Singh Kaushal (student), are scientists at RCB.

National Physical Laboratory (NPL) is a great scientific institution in New Delhi. My first visit to NPL in 1975 was to participate in the National Seminar on Crystallography organized by the then Director, A.R. Verma. Nearly three decades later, the National Seminar was again held at NPL, now organized by the then Director, Krishan Lal. In between, A.P. Mitra. S.K. Joshi, E.S. Rajagopal and Arup Raychaudhuri, all of whom I knew well, worked as Directors of NPL. Although, the scientific activities of NPL are well beyond my areas of specialization, I have had many interactions with the Laboratory. Another institution in the capital with which I had a short term association was the Indira Gandhi National Open University (IGNOU). That was when V.N. Rajasekharan Pillai was the Vice-Chancellor of IGNOU.

Mumbai

The institution that I frequented most in Mumbai has been the Bhabha Atomic Research Centre (BARC). The persons in BARC whom I knew most closely are R. Chidambaram and K.K. Kannan. Chidambaram rose to become the Chairman of the Atomic Energy Commission and then the Principal Scientific Advisor to the Cabinet, Government of India. Kannan, an old friend, initiated and developed macromolecular crystallography studies in BARC. S.K. Sikka is another colleague with whom I have had association spanning several decades. I have been very close to M.V. Hosur, the crystallographer, as well. I worked with B.B. Singh and K.P. Mishra of BARC in IBS. Over the years, I grew close to Mishra. I got to know Raja Ramanna, a former Director of BARC, after he became the Chairman of the Governing Council of IISc. I was reasonably close to P.K. Iyengar who succeeded Ramanna. I was acquainted with

Anil Kakodkar, but did not have the opportunity to work with him closely. I have had a warm relationship with Sreekumar Banerjee who succeeded Kakodkar. Over the decades, I have had multifarious interactions with BARC.

Many faculty members of Tata Institute of Fundamental Research (TIFR), like Girijesh Govil and R.V. Hosur, have been my close friends. As indicated earlier, I have a very special relationship with Girijesh. However, my visits to TIFR were somewhat infrequent. An interesting visit that I remember is as part of an international committee to review the Department of Chemical Sciences. The main thrust of the Department has been NMR and appropriately the Chairman of the committee was Kurt Wuthrich, the Nobel Laureate. I was the only Indian in the four-member committee. Wuthrich was mildly surprised that I, a crystallographer, has been included in a committee to assess a department whose main strength is NMR. In many places, there used to be a mildly antagonistic relationship between crystallographers and NMR specialists. I assured him that not only that I have no antagonism towards NMR, but I was involved in promoting NMR in India! At the end of the review, we had a meeting with the students. One student mentioned that he was happy that he could address his supervisor by his first name. I then said that one could be close to a person irrespective of whether he is addressed by his first name or the surname. I mentioned that I could never have called S. Ramaseshan 'Siv'. I always called him 'Dr. Ramaseshan' or 'Professor Ramaseshan'. On the contrary, I always called Pushpa Bhargava by his first name, although he was much senior to me. The matter is very context dependent. I went on to say that I always called Max Perutz by his first name, even though he was such a distinguished person, so much older than me. Wuthrich also emphasized the culture-dependence of the way in which one addresses a colleague. He said that he and Max Perutz knew each other for a long time. One came from conservative Switzerland and the other had his origin in conservative Austria. Therefore, Wuthrich revealed that he always called Max Perutz 'Dr. Perutz' and in turn he was called 'Dr. Wuthrich' by Max Perutz!

I have had a moderate level of interaction with IIT Bombay. Quite apart from science and technology, the guest house on the banks of the Powai lake comes to mind when I think about IITB. Among the Directors, I knew B. Nag and S.R. Sukhatme slightly. I have had more extensive interactions with Ashok Misra and Devang Khakhar. I have been particularly involved with the Department of Biosciences and Bioengineering. Anil Lala of the Chemistry Department was the main architect of the Biosciences and Bioengineering programme of the Institute. I knew Anil well. He died prematurely and did not see the fruition of his efforts in this area. Among the faculty members of the Department of Biosciences and Bioengineering, I specially remember Dulal Panda and P.V. Balaji. I got to know Ruchi Anand, the crystallographer, who joined the Chemistry Department later on. Other institutions with which

I have had infrequent interactions are Bombay University and Institute of Chemical Technology (ICT).

Advanced Centre for Treatment, Research and Education in Cancer (ACTREC) at Navi Mumbai is a young institution. It is an R&D satellite of Tata Memorial Centre. I began to develop a close relation with ACTREC, particularly after my great grand student Ashok Varma joined the Institute. However, these relationships did not mature fully on account of my immobility.

Hyderabad

My involvement with CCMB dates back to the late 1970s when it was esconced in the Regional Research Laboratory (Subsequently, rechristened as the Indian Institute of Chemical Technology, IICT), Hyderabad. My closeness with Pushpa Bhargava, the Founder Director of CCMB, was an important factor in my early association with CCMB. CCMB came to the national focus after the new CCMB building complex was dedicated to the nation in 1987. The building, as the Centre itself, was conceived and built up by Pushpa. The Deputy Directors at that time were D. Balasubramanian (Balu) and M.R. Das, both my personal friends. The functions associated with the inauguration of the building complex were grand affairs and were spread over several days. They were star studded with the presence of several Nobel Laureates. The main function was presided over by Rajiv Gandhi, the Prime Minister, with Francis Crick as the main speaker. I participated and spoke in many of the events. Interestingly, 25 years later, the inaugural session of the function to commemorate the Silver Jubilee of the 1987 events was presided over by me. One of my pleasant duties was to introduce the past Directors of CCMB. Those whom I introduced and felicitated were Pushpa, H.G. Sharat Chandra and Balu. Lalji Singh, another former Director, could not come. The then Director, C. Mohan Rao was of course, the master of ceremonies.

Between 1987 and the silver jubilee session, I have been involved with CCMB in many different ways. I was also a member of the RC for some time. In addition to those already named, I forged close relationships with many colleagues such as R. Nagaraj, Veena Parnaik, S. Shivaji, Dipankar Chatterjee (who moved to IISc) and Amit Chattopadyaya. The appointment of R. Sankaranarayanan, a former student of mine, to initiate and develop macromolecular crystallography at the Centre, added a new dimension to my relationship with CCMB. I know the present Director of CCMB, Rakesh Mishra, also well. He was a post-doctoral fellow at MBU when I was the Chairman. That Rakesh is also a former student of Allahabad University added to the emotional bond between us.

The Centre for DNA Fingerprinting and Diagnostics (CDFD) started as an off shoot of CCMB, under the tutelage of Lalji Singh. Subsequently it developed into an independent institution supported by DBT. I was a member of their Scientific Advisory Committee (SAC) during 2001-2005. Nirmal Ganguly was then its Chairman.

During that period, I was the Chairman of the SAC of NII and Nirmal, a member. Nirmal used to comment jokingly about our contrasting styles of conducting meetings. The then Director of CDFD, Seyed Hasnain, has been a close friend of mine. I knew well J. Gowrishankar who succeeded Seyed. The person closest to me was Shekhar Mande, who moved from IMTech to CDFD in 2001.

In addition to CCMB and CDFD, with both of which I was closely associated, I have had some interactions with Hyderabad University, Osmania University and National Geophysical Research Institute (NGRI). The person closest to me in Hyderabad University has been E.D. Jemmis who later moved to IISc. Jemmis and I hail from neighbouring villages in Kerala and my father had taught his father. Our friendship with Jemmis and his wife Alice flourished in Bengaluru. M.J. Swamy, to whom reference has already been made, is on the faculty of Hyderabad University. Anong others whom I know well, Goverdhan Mehta and Gautam Desiraju spent much of their independent careers in the University. K. Gopalan of NGRI was senior to me as a student at IISc. He visited us in Oxford when he was returning from USA to India with samples of moon rock from the historic moon landing of 1969. Since then, we have been sporadically in touch with each other. I got to know S.M. Naqvi in the 1980s when we were part of a larger team concerned with chemical evolution and origin and early evolution of life. Three former Directors of NDRI whom I know well are Vinod Gaur, Harsh Gupta and V.P. Dimri. My association with Harsh has been rather extensive, in relation to INSA and ICSU affairs. I got to know Rishi Singh, particularly when he was the scientist-in-charge of CMMACS.

Pune

My most extensive interactions in Pune have been with NCL. I knew well most of the Directors such as L.K. Doraiswamy, Ramesh Mashelkar, Paul Ratnasamy, S. Sivaram and Sourav Pal. T.N. Guru Row and Mohan Badbade, former students of IISc whom I had taught and Ravi Acharya, who was associated with IISc for a few years, worked at NCL for different periods of time. Most importantly, C.G. Suresh, my former student, and Vedavathi Puranik, Kalyani's former student, spent the whole of their independent careers at NCL. Currently, Kiran Kulkarni, a more recent student of ours, is a scientist in the laboratory. John Barnabas also spent time at NCL towards the end of his career. All put together, my involvement with NCL was extensive and personal.

My association with Pune University, was also extensive. I recall my discussions with V.G. Bhide who was the Vice-Chancellor of University in the mid 1980s. The first time I spent a few days in the campus was during the National Space Sciences Symposium in 1983. Since then, I had two main trajectories of my interactions with the University. One involved the Biophysics group of the Department of Physics. My interactions were particularly close with P.S. Damle and P.B. Vidyasagar of the group. I have also been closely associated with the Bioinformatics setup headed by Ashok Kolaskar, who was a former student of MBU. Indira Ghosh was associated with the activities for a number of years. Ashok rose to become the Vice-Chancellor of the University.

The National Centre for Cell Sciences (NCCS) is located within the Pune University campus. My association with the Centre which started when Gyan Mishra was the Director, intensified after Shekhar Mande took over the Directorship. Two grand students of mine, Radha Chauhan and Janesh Kumar, are scientists at the Centre. The senior scientists at NCCS close to me include Yogesh Shauche, a former student of MBU, and Gopal Kundu. Gopal went through a great deal of difficulties, but emerged from them with increased vigour. IISER, Pune is another comparatively new institution with which I have had some association. I know the Founder-Director K.N. Ganesh well from his NCL days. My former student K. Saikrishnan and his wife P. Gayathri, another former student of MBU, are faculty members at IISER.

Chandigarh

I have already referred to my association with the Punjab University, Chandigarh in relation to the revival of the Indian Biophysical Society. That association continued. I am pleased that recently Desh Deepak Singh, a former post-doctoral fellow of mine, joined the Biotechnology Department of the University as Professor. Another institution in Chandigarh with which I have had strong interactions is the Institute of Microbial Technology (IMTech) of CSIR. The interactions commenced when C.M. Gupta was its Director. I and CM shared the 1985 Bhatnagar Prize. From that time onwards, we have been close friends. IMTech then was still in the development stage. In fact, I gave the first lecture in the wonderful IMTech auditorium. I have since given many more lectures in that auditorium. CM was followed by Amit Ghosh as the Director. I and Amit, an upright man, have been good friends. I have been close to the next Director Girish Sahni as well. Girish went on to become DG CSIR. Shekhar Mande's first appointment in India was at IMTech. Anand Bacchawat also joined IMTech at nearly the same time. My former post-doctoral fellow Radhakishan also was in the Institute for some time. S. Srikrishna, a former student of MBU, works at IMTech. Yet another independent scientist at IMTech is S. Karthikeyan, a grand student of mine. Krishan Gopal, a former student of MBU, is a recent appointee at IMTech. I had begun to develop an association with IISER, Mohali, but it could not be sustained for health reasons. The Founder-Director of IISER, Mohali N. Satyamurthy has been a close friend of mine. In particular, I have worked with him in INSA. I have had friends in Post Graduate Institute of Medical Education and Research (PGIMER) and National Institute of Pharmaceutical Education (NIPER), some of whom I have already referred to earlier.

Lucknow

Another institution with which I have had close association is the Central Drug Research Institute (CDRI), Lucknow, of the CSIR. This association became extensive after C.M. Gupta moved from IMTech to CDRI as its Director. I knew well the former Directors Nityanand, M.M. Dhar, B.N. Dhawan and V.P. Kamboj. I was also involved in appointing CM's successor, Tushar Chakraborty. I worked for several years in the RC of CDRI. Among other things, as in the case of many institutions in India, I helped initiate macromolecular crystallography at CDRI. H.S. Subramanya, a former student of MBU, joined CDRI before the turn of the century. He did some brilliant structural work and established the laboratory which I recall inaugurating. He left CDRI as he and his family wanted to move South. Subsequently, Ravishankar Ramachandran and Venkatesh Pratap, both my former students, joined CDRI. Happily, I also inaugurated the X-ray facilities they established in the new CDRI building. I have had some interactions with other CSIR laboratories in Lucknow as well. For a period of time, my friend and old classmate at Allahabad, Ram Prakash Singh was the Vice-Chancellor of Lucknow University. I recall giving a major lecture in the University on his invitation. I have had friends in King George's Medical University, Lucknow as well.

Ahmedabad, Vallabh Vidyanagar

I have visited the Physical Research Laboratory (PRL) a few times to participate in conferences and give lectures. My friends in PRL include J.N. Goswami and Ashok Singhvi. I had close relationship with Indian Institute of Advanced Research (IIAR), Gandhi Nagar when Manju Sharma was involved in its administration and Amit Ghosh was its Director. Desh Deepak Singh commenced his independent career at IIAR. The only time I have directly listened to Narendra Modi was at a function associated with IIAR. He was then the Chief Minister of Gujarat. Although it was only a one off visit, I remember the time I spent in Sardar Patel University, Vallabh Vidyanagar, near Ahmedabad. My Allahabad friend, Ramji Srivastava was then the Head of the Physics Department. Furthermore, my grand student Urmila Patel was then a senior faculty member in the Department. I have many pleasant memories about Ahmedabad and its neighbourhood, the most important of which is a visit to Sabarmati Ashram along with Kalyani.

Mysuru

Central Food Technological Research Institute (CFTRI), Mysuru is another CSIR laboratory in the RC of which I have worked. V. Prakash, a long term Director of CFTRI, has been a personal friend of mine. During my tenure in the RC, M.S. Swaminathan was its Chairman. I enjoyed working with him. He has been very busy and I have stood in for him on several occasions. It is normal for scientists in the laboratory to present their results before the RC. In CFTRI, the presentations were accompanied by food items they have developed, for RC members to taste. Therefore, unless one is careful, RC members might end up with full stomachs by the time the meeting is over! Even when I was not a RC member, I have been involved in many ways with CFTRI. Well before I formally got involved with the laboratory, I had grown close to the four Raos of CFTRI, primarily through the Guha Research Conference. They were Raghavendra Rao, Rama Rao, Narasimha Rao and Rajagopala Rao, all senior to me. It was after my formal relations with CFTRI ended that Ram Rajasekharan, whom I knew well as a student and young faculty member at IISc, became the Director of CFTRI. During that period, Balaji Prakash, a former student of MBU, initiated macromolecular crystallographic studies at the Institute.

Kharagpur

I have already outlined my interactions with IIT Madras, IIT Bombay and IIT Delhi, particularly in relation to organizing the biology programmes in these Institutes. I had occasion to play a similar role in IIT Kharagpur as well. In the late 1990s Amitabha Ghosh, the then Director of IITKh, requested me for help in re-organizing the biology programme in the Institute. For historical reasons, biochemical engineering activities in the Institute were being carried out in the Chemical Engineering Department. This arrangement had begun to cause discomfort. A committee chaired by me examined this issue. Eventually the Department of Biotechnology was strengthened with the addition of most of the concerned faculty of Chemical Engineering and others. In the Department, the person I know best is Amit Das, the crystallographer. I have interacted with him and the Department in several ways. Another faculty member at IITKgp to whom I grew close is Rintu Banerjee.

Roorkee, Guwahati

Although I have visited IIT Roorkee only infrequently, my relation with the structural biologists there has been strong. This is partly because three of the concerned faculty members are my grand students. They are Pravindra Kumar, Shailly Tomar and A.K. Sharma. In addition, I have known Ritu Barthwal, a senior faculty member, for a long time. I have had some association with IIT Guwahati as well. Apart from professional matters, the Guest House located in an ambience of natural splendor, comes to mind when one thinks about IIT Guwahati. IIT Guwahati is located on one side of Brahmaputra while the University is located on the other side. Therefore, I have crossed the great river several times through the bridge over it. Brahmaputra is unlike any other river I have seen in India, in its awe-inspiring magnificence. The person best known to me at IIT Guwahati is Shankar Prasad Kanaujia, a former student of IISc.

Varanasi

The ancient city of Varanasi is steeped in traditional knowledge and wisdom. The academic life of the city, in the modern sense, is dominated by Banaras Hindu University (BHU). Like many other scientists in the country, I have also had interactions with BHU. D.P. Burma (Debida), and Maharani Chakrabarti were one locus of my interactions with the University. Among the old timers, I knew T.R. Anantharaman, the metallurgist and material scientist, and M. S. Kanungo, the biologist, reasonably well. My closest association has been with Subhash Lakhotia, a distinguished biologist and upright human being. Crystallographer/ material scientists, O.N. Srivastava and Dhananjai Pandey have also been close to me.

Bengaluru institutions other than IISc

My interactions with CSIR laboratories have been extensive, many of which have been described earlier. My association with the National Aerospace Laboratories (NAL) Bengaluru was more personal than professorial as Kalyani worked there. In addition to successive Directors some of whom I have referred to earlier, I have many friends who worked in NAL, like S. Krishnan, A.K. Singh and R.V. Krishnan. Kalyani's introduction and association with NAL were through S. Ramaseshan who was the Deputy Director of the laboratory, before moving to IISc as its Director. The name of Ramaseshan occurs at many places in this narrative. We have been very close to Kausalya Ramaseshan and their daughters Arati, Sita and Tara as well. I have also worked in the Managing Committee of the CSIR Centre for Mathematical Modelling and Computer Sciences (CMMACS), an off-shoot of NAL. The Centre was later re-christened as the Fourth Paradigm Institute.

Raman Research Institute (RRI), founded by C.V. Raman after retirement from IISc in 1948, is among the comparatively old scientific institutions in Bengaluru. After Raman passed away in 1970, RRI became an autonomous institution supported by DST. Raman was succeeded as Director by V. Radhakrishnan. We knew him well. I have already referred in detail to N. Kumar who succeeded him. C.V. Vishveshwara, astrophysicist married to Saraswathi of MBU, was a distinguished faculty member of RRI for a number of years. We also knew well S. Chandrasekhar, the well known expert on liquid crystals, and his family. I did not have any scientific collaboration involving RRI, although I have had multifarious interactions with the institution. Kalyani has had a long term collaborative arrangement with Chandrasekhar.

Until a couple of decades ago, much of the basic biological research at Bengaluru was concentrated at IISc. The situation changed by the turn of the century with the establishment of two new institutions in Bengaluru. In 1989, the birth centenary year of Nehru, the Jawaharlal Nehru Centre for Advanced Scientific Research (JNCASR) was established within the IISc campus with C.N.R. Rao as its President. Until 1994, he was concurrently the Director of IISc and President of the J.N. Centre. Eventually, most of the activities of the Centre moved to the campus at Jakkur, although two guest houses of the Centre and President's House remained within the campus. I have had sporadic interactions with the Centre. The Centre has a strong biological component. Two of the senior biology faculty of the Centre, viz, Hemalatha Balaram and Namita Surolia, are well known to us personally and professionally. The Centre was successively led after C.N.R. Rao by V. Krishnan, M.R.S. Rao and V. Nagaraja, all friends of mine form IISc. Particularly, I have worked closely with M.R.S. Rao and Nagaraja. In fact, I have watched Nagaraja growing up professionally.

The second new institution, established in 1992 and has had considerable impact on Indian biology, is the National Centre for Biological Sciences (NCBS). The Centre, founded as an off-shoot of TIFR by Obaid Siddiqui, also functioned within the IISc campus during the first few years. At the turn of the century, NCBS moved to its own premises within the campus of the Agricultural University. As mentioned earlier, I have been close to Obaid. I know well K. VijayRaghavan who succeeded Obaid. I have had a reasonable level of interaction with NCBS. Two senior members of the faculty of the Centre, M.K. Mathew and R. Sowdhamini, have been former students of MBU.

Another institution, though not specifically concerned with biology, which sprang out of IISc, is the National Institute of Advanced Studies (NIAS). In one of his addresses to the Court of IISc, J.R.D. Tata, then its President, emphasized the importance of having a social science component in IISc. That was ostensibly the trigger for establishing NIAS as a separate institution in a few acres of land carved out of the IISc campus, although Tata advocated an outfit as part of IISc. Raja Ramanna, the then Chairman of the Governing Council of IISc, became the Founder-Director of NIAS, after his retirement from the Department of Atomic Energy. Ramanna was succeeded as Director by R. Narasimha, K. Kasturirangan and V.S. Ramamurthy, all friends. I knew well Baldev Raj, who succeeded Ramamurthy. On account of its proximity to IISc and my interest in policy issues, I have had some interactions with NIAS.

The Institute of Bioinformatics and Applied Biotechnology (IBAB) was established in Bengaluru in 2001 at the initiative of Sharat Chandra, Kiran Majumdar Shaw and others, with the full backing of the Government of Karnataka. The Institute has an unconventional structure. Substantial, mainly infra-structural, support is provided by the Government. The rest of the support has to be procured from other sources. Sharat Chandra did the favour of associating me with the establishment and development of IBAB. When the Institute was established, I was the Associate Director of IISc. I was an enthusiastic participant in this effort. IISc has played a major role, perhaps through a process of unobtrusive diffusion, in making Bengaluru the science and technology capital of India. Its role in promoting biology research in the city has been less than what it could have been. Therefore, participation in the establishment of IBAB appeared to be an appropriate way of filling this lacuna.

Manju Bansal was the Founder Director of IBAB. I have known her from her student days and I was confident that she would lay an excellent foundation for the new institution. Indeed, she performed brilliantly. The Indian Institute of Science readily grants deputation to public institutions. There was some ambiguity regarding the nature of the ownership of IBAB and there was considerable discussion on this issue. Eventually, we could make the necessary arrangements to enable Manju to take up the assignment at IBAB. Sharat kindly consulted me on Manju's successor as well. We eventually zoomed on N. Yathindra, an old friend and distinguished colleague who successfully led the GNR department of the Madras University for a number of years. Building on sound foundations, he raised IBAB to the present eminent level. I was also involved in selecting Yathindra's successor H.S. Subramanya, an excellent scientist and human being, whom I have already referred to.

Until a few years ago, when my physical mobility was not impaired, and especially during my close engagement with the INSA, I was involved with granting agencies of the Government of India. The terms under which grants are given by these agencies are different for public and private institutions. In this respect, there were doubts about IBAB in the minds of many in positions of authority. To my mind, IBAB is an autonomous institution supported by the Karnataka government, but unencumbered by governmental bureaucracy. Ultimately, this view prevailed and IBAB was enabled to receive funds on terms appropriate for public institutions. IBAB has now grown into an excellent vibrant institution. I rejoice in it. IBAB has still retained me in their Governing Body. As a corollary, I have had association with the Centre for Human Genetics, Bengaluru, an organization led by Sharat Chandra.

The GKVK campus of Bangalore Agricultural University has been a favourite destination for meetings such as those associated with the FIST programme. Therefore, I have visited the campus several times. Through these meetings and several other activities, I grew close to M. Udaya Kumar, a senior scientist at the University. Udaya Kumar has been a self-effacing, but effective leader of science. My interactions with other educational institutions in Bengaluru were largely confined to giving lectures.

Other Public Funded institutions

The CSIR Laboratories with which I have had close interactions have already been described. In addition, I had sporadic interactions with IICT, National Institute of Interdisciplinary Science and Technology (NIIST), Thiruvananthapuram and National Institute of Oceanography (NIO) Goa. The other public funded institutions with which I have had infrequent interactions include Bharathidasan University, Trichi; Madurai Kamaraj University (MKU); North Eastern Hill University

(NEHU); IISER Thiruvananthapuram; NISER, Bhuvaneshwar; Pondicherry University; National Institute of Technology (NIT), Kozhikode; Anna University, Chennai and Indira Gandhi Centre for Atomic Research (IGCAR), Kalpakkam. Many who worked in these institutions have been close friends. The Founder-Director of IISER, Thiruvananthapuram, E.D. Jemmis and his family have been close to us while he was at Hyderabad and Bengaluru as well. I had taught T.K. Chandrasekhar, Founder-Director of NISER, Bhuvaneshwar when he was a student of IISc. I have interacted with him when he was the Director of NIIST, Thiruvananthapuram and Secretary of SERB, as well. Pramod Tandon of NEHU has been a personal friend. So have been M. Lakshmanan of Bharathidasan University and S. Krishnaswamy of MKU. I have already referred to my friend P.K. Ponnuswamy who has been associated with both these institutions in addition to Madras University. I recall my pleasant interactions with P.P. Mathur of Pondicherry University. A former post-doc of mine, R. Krishna is a faculty member of that University. I grew close to P. Gautam of Anna University who is a former student of IISc. Among the friends and colleagues at Kalpakkam, I remember Placid Rodriguez, the most.

Private Universities

The institutions with which I interacted have been almost exclusively public funded ones. Comparatively recently, I developed some interactions with private institutions as well. The first of these was with the Vellore Institute of Technology (VIT), mainly thanks to M.A. Vijayalakshmi and DST. Vijayalakshmi, a distinguished scientist, returned to India in 2005, after working in France for about 40 years. She established the Centre for Bio-separation Technology (CBST) at VIT under the High Priority Research Area Programme of DST. I have been for a long time a member of the Steering Committee of the Centre, chaired by R. Kumar. Later, I succeeded Kumar as the Chairman of the Steering Committee. Vijayalakshmi and her colleagues developed CBST into a fine organization which combined in itself excellent basic investigations and useful translational research, with the full support of the VIT management. In spite of her long stay in Europe, Vijayalakshmi remains very Indian. In addition to being an eminent scientist and achiever, she is a splendid and warm human being. Kalyani and I grew close to her. I also had occasion to interact with G. Viswanathan, the Founder and Chancellor of VIT. I greatly respect his vision, commitment and acumen.

Over the years, I got involved with SASTRA University, Thanjavur, as well. Many faculty members of the University had made presentations before grant-giving committees chaired by me. I was impressed with their work. However, my direct interactions with the University were catalyzed by V.S. Ramamurthy. He arranged for me to hand over the Ramanujan Prize, instituted by SASTRA, for the year 2009. The international Prize is awarded to a young mathematician every year on the basis of global competition. Kalyani and I visited Thanjavur and Kumbakonam for this purpose in December 2009. We also visited Ramanujan's house at Kumbakonam, maintained by SASTRA. We also used the occasion to visit Mannargudi where Kalyani's ancestors used to live. At Thanjavur and Kumbakonam, we had extensive interactions with the faculty and students of the University and visited several facilities. My association with the University continued. Two of my former post-docs, N.T. Saraswathi and S. Thamothran are faculty members at SASTRA. The last time we visited the University was when I was presented with the first SASTRA-G.N. Ramachandran Award in 2014. I have been a member of the Selection Committee for the award in subsequent years. I have met R. Sethuraman, the Vice-Chancellor, only briefly on a couple of occasions. That was enough for him to claim my respect and admiration. I have had extensive interactions with S. Swaminathan, a biologist and Dean of Planning and Development. I have been impressed not only by his competence but also by his personal qualities which include humility.

I was in the process of developing relations with Jain University, Bengaluru and GITAM University, Vishakapatnam. However, I became physically immobile before the relations could mature. My association with the Jain University was brought about by C.G. Krishna Das Nair, the Chancellor of the University. Krishna Das Nair has had a very distinguished career, including as the Chairman of HAL. I have interacted with him and his wife sporadically. Interactions with Nair became closer when we were on the Board of Governors of NIT, Kozhikode, of which he was the Chairman.

Structure of Indian Science. Some observations

My familiarity with the science departments of the Government of India and several institutions across the country, emboldens me to make a few general observations. The scientific establishment in the country is reasonably robust and has delivered, although there are many aspects of it which merit improvement or overhauling. Essentially, as I have often said, we need a vibrant, resilient and sensitive system which is less bureaucratic, less hierarchical, more autonomous and more participatory. I have elaborated my views on the matter, as is my wont, in a few *Current Science* articles. I only touch upon the issues here. My approach has been to use the positive aspects of the system to the maximum possible extent, while at the same time contributing to its improvement.

Deployment of available resources is an area which needs attention. The available resources are extremely scarce in comparison to many other countries such as China, a country with which we can be justifiably compared in terms of size, population and state of development. In 2015, the R&D expenditure in India was about 0.85% of GDP while it was 2.1% in China. The GDP of China is 2.39 to 5.06 times that of India depending on the way it is calculated. Thus, the R&D expenditure in China is roughly 6 to 12 times that in India. Therefore, even in terms of R&D expenditure, it is inappropriate to compare the performances of India and China, in science and technology. It is like pitting a half-starved person against a healthy, well-looked after person in a competitive race. Allocation of resources become all the more crucial when they are scarce.

Extra-mural support, particularly competitive research grants, is central to the research endeavours of any country. Such support should therefore form a substantial chunk of the total R&D outlay. An impression has gained ground that emerging emphasis of science departments is now shifting to institutions and mega top-down projects, at the expense of extramural support. If true, this trend is deleterious to Indian science and needs to be reversed. The ease with which research grants can be operated is also a major issue. Different agencies use different sets of bureaucratic procedures to regulate operations. Some of them are debilitating. To my mind, the procedures earlier followed by DST-SERC by and large constitute the gold standard although there is considerable room for improvement. I always felt that one can evolve a set of excellent procedures if one combines the positive features of the different procedures followed by different science departments. I have taken up this issue with many in authority. However, I am not aware of any progress made in this direction.

Autonomy of agencies and institutions is another important issue. Among the government departments, the so-called strategic departments, viz, DAE, DOS and DRDO, enjoy considerable autonomy. In the present day world, the areas such as Information and Communication Technology and Biotechnology also have strategic importance. I see no reason why the level of autonomy enjoyed by DAE, DOS and DRDO, could not be extended to all science departments. In the case of institutions, erosion of autonomy is a major concern. Academic institutions, particularly institutions of higher learning and research, can thrive only when they are substantially autonomous. As I have argued earlier in this narrative, autonomy does not mean that of the Head of Institution and the governing body. Autonomy should percolate through different levels to individual scientists, with appropriate safeguards depending on the nature of the institution. Thus, autonomy and internal democracy should go hand in hand. I have elaborated this aspect when dealing with IISc (Chapter 6). Autonomy is of course not absolute. It should operate within the limits prescribed by the mandate of the institution and the overall establishment framework prescribed by the government. Furthermore, any organization which receives public funds is accountable within the accounts-audit set up of the government. Even within the broad limits, autonomy, if granted, provides the institution with considerable freedom of action. In fact, autonomy, internal democracy and accountability are components of a single package.

Autonomous institutions with internal democracy should work as a system, based on generally accepted administrative procedures and conventions. This is by and large true about institutions like IISc and IITs. The Director and other scientists holding high administrative positions are important, but the functioning of the institution is not totally dependent on them. Many smaller research institutions, including some which have performed well, are inordinately Director-centric. This is not healthy in the long run. However, these institutions are too small for the development of robust systems of governance. There is a case for expanding them to reasonable sizes. In any case, a critical mass is necessary to make an impact. By global standards, even IISc and IITs are moderately sized institutions. Each one of them could benefit by substantial expansion. Our institutions of higher learning and research need to make greater impact nationally and internationally than they do now. In this context, the size of institutions merits critical examination.

I cherish the associations I have had with agencies and institutions. In addition to professional rewards, these associations have resulted in many enduring friendships.

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ENGAGEMENT WITH KERALA. THE SECOND INNINGS

My intense involvement with Kerala society during my early youth has already been outlined in the beginning of this narrative. I left Kerala in 1961 for Allahabad to pursue my M.Sc. course. Since then, I have never lived in Kerala, although I have been in constant touch with my extended family and relatives in the state. From Allahabad I went to Bengaluru to pursue my Ph.D. programme at IISc and then to Oxford for post-doctoral work, to return to IISc in 1971. During this period, I never had any significant involvement with public affairs in Kerala, although I used to follow developments in the State with interest. My engagement with Kerala started again on a low note in the 1970s and reached a stable level in the 1990s. I continued with this engagement until I became substantially immobile.

My approach towards agencies and institutions in Kerala has been in a sense the same as that I adopted in relation to national agencies and institutions. I never took up administrative positions although I have been sounded out on my willingness to occupy positions such as Headship of the Kerala State Council for Science, Technology and Environment (concurrently, Principal Secretary to the Government of Kerala) and Vice-Chancellorships of different state Universities. I always politely declined to be considered for such positions, not because these positions are not important, but because occupying them would prejudice my main career objective of building up structural biology, particularly macromolecular crystallography, in India. However, I enthusiastically participated in different activities as part of, often as Chairman of, various advisory bodies.

Presentation of Kerala Science Awards in 2012 to E.C.G. Sudarashan (extreme left) and Vijayan by Chief Minister Oommen Chandy (second from left). V.N. Rajasekharan Pillai is at the extreme right.

Vijayan introducing Ada Yonath in a function in Thiruvananthapuram in 2013. Rajasekharan Pillai is also seen.

M.A. baby speaking after releasing Vijayan's Malayalam memoirs in 2016. Seated in the front row (L to R) : Rajasekharan Pillai, Vijayan, M.P. Parameswaran, C.P. Narayanan, journalist K.P. Mohanan, Kavumbai Balakrishnan. At the extreme right in the back row Kalyani and Devi.

Prof. Rajan Gurukkal, Vice-Chancellor of Mahatma Gandhi University, presenting a memento to Dr. Vijayan.
(courtesy thehindu.com)

Kerala Sastra Sahitya Parishad

Kerala Sastra Sahitya Parishad (KSSP) was founded in 1962 with the main objective of producing science literature in Malayalam. Eventually, the scope of the activities of KSSP expanded around the motto “Science for social revolution”. KSSP is perhaps the most important component of the peoples’ science movement in India. One of its early efforts, which attracted national and even international attention, was as the spearhead of the agitation against the silent valley project in the 1970s and the 1980s. The Parishad received the Indira Gandhi Paryavaran Puraskar in 1988. International recognition came in the form of Right Livelihood Award in 1996. The influence of KSSP on the public life of Kerala has been very considerable and multi-faceted.

I had never been an activist of KSSP or its office bearer. Except in relation to a couple of specific assignments, my involvement with KSSP has been sporadic. However, I always emotionally belonged to KSSP.

I have known some of the early leaders of KSSP. P.T. Bhaskara Panicker was prominent among them. By the time I got to know him, he was already a father figure. He was very affectionate to me. Panicker was a great scholar, committed political activist, educationist and an extraordinarily kind human being. An event that made him well known was his election as the President of the Malabar District Board in 1954. Northern Kerala which is often referred to as Malabar and now made up of four districts, was then part of the Madras presidency. His Presidentship of the Board was characterized by remarkable compassion towards the employees including teachers who worked in Board schools. The great Malayalam novelist Cherukad is said to have made an interesting observation about Panicker. One can debate whether there is God or not. If there is God, Cherukad said, he would be like P.T. Bhaskara Panicker! I was indeed honoured when I was invited to give the P.T. Bhaskara Panicker Memorial Lecture at the Kerala Science Congress in 2009.

Another early leader of KSSP was N.V. Krishna Warrier who was a poet, thinker, journalist, educationist, all rolled into one. Yet another early leader, who is regarded as the Founder of KSSP, was K.G. Adiyodi, the distinguished zoologist and educationist. During our first stint in Oxford, Adiyodi and his wife Rita spent an extended period in the University. We got to know them well. The last time I met Adiyodi was in a function at Kottayam when he was the Vice-Chancellor in charge of Mahatma Gandhi University.

M.P. Parameswaran has been the main conduit for my interactions with KSSP. Parameswaran, with a doctorate in Nuclear Engineering, had a secure job with good prospects in BARC. He left the job when he was still young to plunge into social and political activities in Kerala. He became an acknowledged leader of KSSP. He has a substantial national presence also in peoples’ science movement and educational activities. A simple man with a grand vision, he is a combination of an activist and sage. Parameswaran and I have been friends for decades and on many occasions I was involved in Parishad activities at his suggestion.

In 1993 I was invited to inaugurate the 30th anniversary meeting of KSSP. The meeting was held at Sri Kerala Varma College, my Alma mater at Thrissur, which was in the late 1950s the venue of much of my student political activities. I had then made innumerable speeches in Malayalam on the campus. After I left Kerala, I had no opportunity to speak publically in Malayalam. Thus in 1993, I was attempting to make a major speech for an hour in Malayalam, that too at the venue which has witnessed my Malayalam speeches more than 30 years ago! Therefore, I approached the event with some trepidation. However, my uneasiness vanished when I began to speak, with so many of my friends on the dais and in the audience. With that speech, my nervousness about lecturing in Malayalam came to an end. The topic given to me for the inaugural lecture was "Technology appropriate for Kerala". In addition to technology needed for the traditional industries and agriculture of Kerala, I argued that those appropriate for Kerala are Information Technology (IT) and Biotechnology (BT). I was perhaps the first to formally point out the appropriateness of those technologies for the state. This appeared to be interesting in retrospect in view of the boom of IT in Kerala, although it is largely confined to use of products developed elsewhere. In my address, I also made some sharp critical comments on the structure of higher education in Kerala. I also warned about the danger of societal involvement in management, degenerating into gross interference in the internal affairs of the institutions. I anticipated some resentment among the activists, when I made these statements. On the contrary, many of them congratulated me for doing so. They said that they had similar views, but were not in a position to publically air them. They were happy that I gave public expression to their concerns.

The work of the Kerala Education Commission set up by KSSP was probably the most important activity of the Parishad I took part in. The Commission which worked during the second half of 1990s was chaired by Ashok Mitra, the distinguished economist, educationist, Member of Parliament and former Finance Minister of West Bengal. The other members were S. Anandalakshmy, N. Balakrishnan Nair, K. Gopalan, T.N. Jayachandran, C.T. Kurien, K.N. Panikkar, and P.K. Umashankar, all distinguished persons in their respective fields. In the course of the work of the Commission, I grew particularly close to Balakrishnan Nair, the scientist; Jayachandran, an administrator and educationist; C.T. Kurien, the economist and K.N. Panikkar, the historian.

The secretarial team which assisted the Commission was equally star studded. The team consisted of M.P. Parameswaran, C.P. Narayanan, R.V.G. Menon, O.M. Shankaran, C. Ramakrishnan and K.N. Ganesh. I already knew Parameswaran very well. The others became my friends. In particular, my friendship with C.P. Narayanan matured over the years. C.P. is a well balanced intellectual and educationist. The many roles played by him include that of a Member of Parliament. The two persons whom I often consulted on various issues and sought advice from, have been M.P. Parameswaran and C.P. Narayanan. I also subsequently became close to Kavumbayi Balakrishnan. While working at Kerala Varma College as a faculty member, he had been deeply involved in the affairs of the college. Since then, his role was central to the publication activities of KSSP.

The constitution of the Commission was announced in November 1995. The report of the Commission was finalized by the end of 1998. The Commission and several Task Forces constituted by it met many times. The Commission had detailed discussions with all stake holders at locations throughout the length and breadth of Kerala (Kerala does not have much of breadth!). Those with whom the Commission had face to face discussions included political leaders, literary figures, educationists, representatives of teachers and students and those involved in the management of public and private educational institutions. In addition, written comments were sought and obtained from hundreds of persons belonging to different walks of life. To me, and I am sure to others as well, working in the Commission was an educative experience. We got a reasonable picture of the education scenario in Kerala, with all its complexities and nuances. The 150 page report we prepared dealt with all aspects of education in Kerala.

The report was well balanced and addressed the concerns of all stake holders. The report thus has been a valuable document. However, in a politically polarized state like Kerala, a well balanced document can turn out to be nobody's baby. Probably that is what happened in the case of the report of the Commission. The pink tinge attributed to KSSP meant that the Right was not favourably disposed towards a report produced under its aegis. All that the report said were not what the Left wanted to hear. In particular, the part of the report dealing with financing of education, did not gel with the competitive populism which resulted in making higher education in the government sector almost free even for the rich and the very rich. Perhaps, the references in the report to autonomy were also not in consonance with the culture of interference in the internal affairs of educational institutions by politicians and other interested groups. Thus, the report appeared to have fallen between stools. The report of the Commission did not receive the attention and consideration it deserved. In my view, most of the recommendations of the Commission are still very relevant.

After my involvement with the 30th anniversary of KSSP and, more particularly, with the Education Commission, I developed close relationships with the leaders and workers of the Parishad and engagement with KSSP increased substantially. In terms of specific assignments, 2013 has been important. On Febraury 25, I inaugurated the annual meeting of the All India

Peoples' Science Network in Lucknow. I deem it an hounour to have been invited to do so. KSSP is an important component of the network. My friends M.P. Parameswaran, C.P. Narayanan and others were also present at the meeting. Subsequently, I felt again honoured when I was invited to inaugurate the Golden Jubilee annual meeting of KSSP at Kozhikode on May 10. The other speakers at the inaugural session were Mahatab Bamji, who is like an elder sister to me, and Satyajit Rath, a dear friend from NII. I chose 'Modern biology and its societal implications' as the theme of my lecture. The event was not long after I and my colleagues in the Science Academies were stung by a malicious campaign by interested parties, partly on account of misunderstanding about modern biology. Therefore, I was in a combative mood and expanded the scope of the lecture. I spoke about aggressive predatory capitalism, its twin brother excessive consumerism and the environmental degradation that the two have brought about. The two have had other undesirable consequences as well. There is a tendency among some people to blame science and technology for these consequences. Vested interests, particularly those who want to keep India underdeveloped, are among them. Especially, food surplus countries in the advanced West have a vested interest in keeping the productivity of Indian agriculture at a low level. In fact, it would appear that there is a nexus among various vested interests, pseudo scientists, revivalists and other assorted activists, for attacking reason-based and evidence-based scientific approach. I emphasized the need to be vigilant against them. We need to strive for a developmental model involving environmental protection. In Kerala, it is time for a second renaissance based on such a model with emphasis on science, reason and humanity.

Many friends, specially the late N. Seshagiri, used to urge me to write my memoirs, particularly in relation to the initiation and development of macromolecular crystallography in India. That would be a major undertaking. I also realized that I have had an interesting life, though short, as a student and political activist in Kerala. I did not get around to writing any memoir until I had to spend a few weeks in two installments in an Ayurveda hospital where I had time in between treatments. It was appropriate to write about my early life in Kerala in Malayalam. I had doubts about writing properly in Malayalam. However, when I got started, my old skill in Malayalam writing came back. I sent the short piece to M.P. Parameswaran. He was very favourably impressed and passed on the manuscript to Kavumbayi Balakrishnan. Initially, he wanted me to expand the piece to cover my whole life, which I was not ready to do. As a compromise, we decided to add my tenure as a Ph.D. student at IISc and that as a post-doctoral fellow in Oxford also to the narrative. Thus, the new manuscript covered my life until 1971 when I started my career as an independent scientist after completing the whole of my research training.

In the meantime, I got acquainted with the well known historian and educationist Rajan Gurukkal. I have directly interacted with him earlier once when I visited Mahatma Gandhi University, Kottayam for official work as well as for giving a lecture, while he was the Vice-Chancellor of the University. After formal retirement, Rajan has been on and off Visiting Professor at the Centre for Contemporary Studies at IISc. During this period, Rajan and I became close friends. I have all along been an admirer of Rajan as a scholar and writer and my interactions with him served to enhance the admiration. I requested him to go through the manuscript of my memoirs. He readily did so and felt that it is eminently publishable. That gave me confidence to go ahead with publishing my memoirs.

There was more than one option for the publisher. My choice was clearly KSSP on account of my long association with it. Parameswaran and Balakrishnan readily agreed with my choice. We decided to call the piece the Malayalam equivalent of 'Politics to Scientific Research'. I requested Rajan to write the Foreword to the book. To my great delight, he readily agreed to do so. Within a few days, he handed over the Foreword which was so beautifully written that I could not have asked for anything better. The typescript of the material was prepared by my brother Ravindran at Farook. He also contributed in many ways in the organization of the book. My Malayalee student Anu Chandran helped in giving the final touches to the typescript.

The book was released on March 19, 2016 in the Kerala Sahitya Academy auditorium at Thrissur, by M.A. Baby. M.A. Baby is a well known political leader. He became a Member of Parliament at an early age of 32 years. He has had a distinguished career as a parliamentarian. Among other things, he was the Minister of Education and Cultural Affairs in the Kerala Government during 2006-2011. An erudite leader, Baby conducted himself with dignity. His interests extended well beyond politics. He reached out to artists, litterateurs, scientists and other intellectuals. It is in consonance with this practice that Baby contacted me when he was a Minister and I, the President of INSA. Kalyani and I developed an instant rapport with him in the first meeting itself. He could discuss left ideology, carnatic music and the latest development in Latin American politics with equal ease. I recall Bruce Alberts, a former President of the US National Academy of Sciences, mentioning to me during a dinner at Amsterdam, how impressed he was with Baby on the basis of a conversation Bruce Alberts had with him. My interactions with Baby have been primarily during the period when he was a minister. However, the warmth of our relationship continued. I was touched when he took time off from a hectic election campaign to release my book.

Baby's speech after releasing the book was a comprehensive review of its contents. M.P. Parameswaran, C.P. Narayanan and Kavumbayi Balakrishnan, all my friends from KSSP, and K.P. Mohanan, the journalist, were among the speakers on the occasion. I was deeply touched when V.N. Rajasekharan Pillai made it a point to come to the function and make appreciative remarks. In addition to Kalyani and Devi, many of my extended family members were also present at the function. Happily, many of my old friends and colleagues also attended the function. The publication of my memoirs by KSSP was an appropriate culmination of my association with the great organization.

Government agencies

The Kerala State Committee on Science and Technology was constituted in 1972 when C. Achutha Menon was the Chief Minister. Achutha Menon shared many attributes of Jawaharlal Nehru whom he greatly admired. One of them was commitment to Science and Technology. He was aware of the weakness of Kerala in high level S&T research. It was as an attempt to fill this lacuna that the State Committee was constituted. The Committee was reconstituted as Science, Technology and Environment Committee (STEC) in 1981. A further reconstitution in 2002 resulted in the Kerala State Council for Science, Technology and Environment (KSCSTE). For historical reasons, even now KSCSTE is often referred to as STEC. The Council is chaired by the Chief Minister. The *de facto* head of the Council is the Executive Vice-President (EVP) who is also the Principal Secretary of the Government Department of Science, Technology and Environment. Half a dozen research institutions dealing with different areas were also established, with STEC having oversight responsibility. The offices of the Council are ensconced in Sastra Bhavan at Pattom in Thiruvananthapuram.

I first became a member of the Kerala State Committee on Science and Technology in 1981. Since then, I have served on the Committee and its reconstituted versions several times, though not continuously. Among the Chairmen of STEC with whom I worked, I had an easy rapport with A.D. Damodaran. Damodaran was a scientist associated with DAE before he became the Director of the then RRL of CSIR in Thiruvananthapuram. His contributions to STEC have been considerable. I admire him greatly for his independent stands and views. Damodaran was followed by M.R. Das, a personal friend. His monumental contribution was the establishment of the Rajiv Gandhi Centre for Biotechnology (RGCB) as its Founder-Director. C.G. Ramachandran Nair is a former Chairman of STEC, whom I hold in high esteem. A distinguished chemist, administrator and prolific writer, CGR has had considerable impact on the intellectual life of Kerala. I have had sporadic interactions with him for several decades.

The appointment of M.S. Valiathan as the EVP of KSCSTE and Principal Secretary of the Government of Kerala, after the turn of the century, was a harbinger of hectic activities in the following years. Valiathan has been a distinguished surgeon, excellent scientist, exponent of Ayurveda and institution builder. The period of his headship of KSCSTE substantially overlapped with his tenure as President of INSA (2002, 2003, 2004). On his suggestion, I got seriously involved with the work on KSCSTE. I became the Chairman of its Research Council in 2003. The Research Council was involved in assessing research proposals and disbursing funds. Here again, I used the process as a mentoring exercise. Through this process, I gained a reasonable understanding of the state of science in Kerala. I also developed many friendships among the members of the Council and the investigators. During this period, I also worked on the Kerala Biotechnology Commission and was involved in formulating Kerala Biotechnology policy. Joe Thomas was the Chairman of the concerned committees. I recall hosting a major meeting of the committee at the office of the Associate Director, IISc. Even after Valiathan left, I was involved in this activity till 2011. I worked closely with Valiathan's successors, viz, A.E, Muthunayagam, E.P. Yeshodharan and C.T.S. Nair. The different engagements I have had with KSCSTE for nearly a decade are too numerous to be mentioned here. I had become almost a permanent fixture of Sastra Bhavan!

My association with KSCSTE continued after 2011, particularly when my friend V.N. Rajasekharan Pillai was the Head of the organization. I was on the Advisory Board of the Srinivasa Ramanujan Institute for Basic Sciences (SRIBS) at Pampady, established on the initiative of Rajasekharan. I recall working with him in the organization of a National colloquium at Thiruvananthapuram in 2013 to mark the 100th year of X-ray crystallography. On that occasion, the Nobel Laureate Ada Yonath gave the G.N. Ramachandran lecture. I know Ada Yonath well and contributed to persuading her to come to Thiruvananthapuram. By the time Suresh Das took over as the EVP of KSCSTE, I was too immobile to participate in the activities of the organization. My last assignment on behalf of KSCSTE was as a member of the Selection Committee to choose the recipient of the 2014 Kerala Sastra Puraskaram (Science Prize).

I have had excellent relations with the officers and staff of KSCSTE. I was impressed with their work during my long stint as the Chairman of the Research Council. The quality of their work was as good as, if not better than, that of the officers at some of the national granting agencies. Among the leaders of KSCSTE, the one closest to me has been R. Prakashkumar. I have known him for decades. He is an excellent administrator and accomplished scientist. Currently, he is the Director of the Jawaharlal Nehru Tropical Botanical Garden and Research Institute at Palode near Thiruvananthapuram. Earlier, he has led the Malabar Botanical Garden and Institute of Plant Sciences at Kozhikode.

In 2011, the Government through KSCSTE instituted the Kerala Sastra Puraskaram to be presented each year on the recommendation of a high power expert committee. The 2011 Prize was given to E.C.G. Sudarshan, the outstanding Nobel class physicist. The 2012 prize was awarded to me. The two prizes were handed over at the same time by the then Chief Minister of Kerala, Oommen Chandy, at an impressive function in Thiruvananthapuram. Needless to add that I was overjoyed at being recognized thus, along with Sudarshan, by my home state. Valiathan was the recipient of the 2013 prize. I felt that I was sandwiched between two great scientists and leaders of science. I was very happy when the 2014 prize was given to my friend and colleague K.P. Gopinathan. Soon after the award of the prize to me, I was elected as the Honorary Fellow of the Kerala Academy of Sciences, in 2013, along with a galaxy of nationally renowned Malayalee scientists of India. I am grateful to Oommen V Oommen, the then President of the Academy and his colleagues, for this honour. I have interacted with Oommen Oommen on other occasions as well.

I, along with Kalyani, met the Chief Minister Oommen Chandy for the first time at the Sastra Puraskaram function. I later shared the dais with him on the occasion of the G.N. Ramachandran lecture by Ada Yonath. I also attended a meeting of the Advisory Board of the Ramanujan Institute, chaired by him. From these brief interactions, Oommen Chandy impressed us as a thorough gentleman with impeccable manners.

I also have had the opportunity to work on a few committees associated with the Kerala Government. I particularly remember my association with the Kerala State Higher Education Council, then headed by K.N. Panikkar. I chaired a committee of the Council on restructuring of undergraduate education in Kerala. The recommendations of our committee were well received and some implemented. I enjoyed working with K.N. Panikkar and his colleagues, but I could not contribute as much as I would have liked to, as I became the president of INSA soon after the Committee started its work.

Although not connected with the Government, an event which made a deep impression on me was the International Congress on Kerala Studies, in 1994, organized under the leadership of E.M.S. Nambudiripad, the first Chief Minister of Kerala. I have already referred to him in the early stages of the narrative. He has been probably the most influential leader of Kerala in modern times. He was, and is, highly respected even by his political opponents. He sent personal invitations to all the potenial participants, which was difficult to resist. Consequently, a couple of thousands of scholars and activists from India and abroad participated in the Congress. I deem it an honour to have had the opportunity to participate in the Congress and give a lecture in an appropriate session. The Congress started with a comprehensive inaugural discourse by EMS. Among other things, he expressed happiness at the appreciative comments on the famous Kerala Model (of which he was the chief architect). However, he pointed out a specific problem with the development efforts in Kerala. Kerala has always been deficit in food. The land used for agriculture progressively shrank. Kerala is also industrially weak. The development has been mainly in the service sector. He wondered how long this situation could be sustained. A quarter of a century on, the problem has only become more acute.

Institutions

Perhaps my most intense interactions with an institution in Kerala were with RGCB, particularly when M.R. Das was its Founder-Director (1994-2001). RGCB was established and was under the administrative control of STEC/KSCSTE. It is indeed a Herculean task to establish and nurture a vibrant scientific organization under the aegis of the state Government. Das did that admirably. It was particularly important to resist local pressures on appointments etc. Das did this primarily by involving a few senior scientists who are beyond the pale of local influence, in appointments and other activities. I was one of them. My Kerala connection added to the intensity of my involvement. The Centre started on rented premises. Its own building was constructed under the supervision of Das. The building was inaugurated by Abdul Kalam, the then President of India. Kalyani and I participated in this inaugural function. The event concluded with an impressive dance performance by Shobhana that evening.

My association with the Centre continued even after M.R. Das retired, but with reduced intensity. I was a member of the selection committee to identify the successor to Das. We chose R.V. Thampan, an endocrinologist, who was by then already employed at RGCB. Incidentally, Thampan had spent time in my laboratory in an early stage of his career. Thampan was succeeded by the dynamic M. Radhakrishna Pillai, a cancer biologist. I have frequently interacted and have had very good relations with him. Radhakrishna Pillai has had a long innings as the Director. In the meantime, the Centre was taken over by the DBT. RGCB is now an autonomous society with DBT as the administrative department. I continue to be a member of the Society. Needless to add, I developed many warm relationships at RGCB.

Among the universities of Kerala, my association was the closest with the Mahatma Gandhi (MG) University, originally known as Gandhiji University, located at Kottayam. The University was established in 1983. M.A. Ittyachen of the School of Pure and Applied Physics has been among the earliest faculty members who joined the University. I got to know him well. My first visit to the University was in 1987 when he organized the National Seminar on Crystallography. Pending the construction of the campus at Kottayam, the meeting was held at Changanacheri. U.R. Ananthamurthy was then the Vice-Chancellor of the University. By then, V.N. Rajasekharan Pillai had joined the University to lead the chemistry activities. Over the decades, Rajasekharan and his family became close to Kalyani and myself. He went on to occupy many important positions in different parts of India and in national agencies.

Ittyachen organized the National Seminar on Crystallography in 1997 as well, now in the new campus at Kottayam. By then Rajasekharan had become the Vice-Chancellor of the University. My association with the University was strengthened by the presence of persons of my lineage in the faculty. Those who joined the M.G. University included my grand student M. Haridas and my former post-doctoral fellows C. Sudarsana Kumar and C. Sadasivan. Haridas and Sadasivan moved to northern Kerala when the Kannur University was established. Rajan Gurukkal was the Vice-Chancellor when I visited the M.G. University for the last time.

CMS College, Kottayam is the first college to be established in Kerala. It has played a central role in the higher education sector of the state. I recall giving lectures a couple of times in the hallowed precincts of the CMS College. I particularly remember an occasion when Sachin Tendulkar started batting in a test match at Chennai just before I commenced my lecture. I was not sure whether those in the audience wanted to listen to me or to watch Tendulkar on the television. In the beginning of my lecture, I assured them that Tendulkar would still be batting when I finished my lecture. In fact, he continued to bat for much longer in a memorable innings. Kumarakom was another major attraction in the neighbourhood of Kottayam. I have visited Kumarakom a few times alone as well as with Kalyani.

After Haridas and Sadasivan moved North, I had some interactions with Kannur University as well. One of the graduate students of Haridas, K. Geethanandan, was with me as a post doctoral fellow. Remarkably, he carried out his researches while he was a secondary school teacher.

I am a graduate of the Kerala University. The first time I visited the University was in 1960 to procure my B.Sc. mark list. For some reasons, which I do not remember now, I needed the mark list urgently. My subsequent visits to the University were decades later. I have lectured in the University off and on. C.G. Ramachandran Nair, who has already been referred to, has been the Head of the Chemistry Department, Dean and much else in the University. My contemporary and friend in IISc C.P. Prabhakaran was a faculty member in chemistry. My batchmate in the Ph.D. programme S. Devanarayanan worked for long in the Physics Department. I have interacted extensively with P.R. Sudhakaran of the Biochemistry Department. Among the Vice-Chancellors, the person whom I knew best was B. Ekbal. Ekbal, a neurosurgeon by profession, has been a political and social activist, educationist and prolific writer. I also knew A. Jayakrishnan well. In fact, I was involved in his appointment as Professor at IIT Madras, from where he came on deputation in 2008 to assume the Vice-Chancellorship of the University. I always admired his never-say-die spirit. I also recall with pleasure my association with C.M.K. Nair, an old graduate student of mine, who worked for long in the Mahatma Gandhi College at Thiruvananthapuram.

I have had sporadic relations with many other institutions in Kerala, primarily through giving scientific talks. The two institutions where I studied were C.N.N. Boys High School, Cherpu and Sri Kerala Varma College at Thrissur. I have already referred to the role of Kerala Varma College in shaping my persona. After I left Kerala, my association with the college was largely confined to contributing articles to commomerative souvenirs.

The Cherpu School has been very special to our family. My father worked during the whole of his professional life in the school and retired as its Head

Master. The entire school education of my siblings and myself was in Cherpu school. In later life, we have contributed in minor ways to the well being of the school. The most memorable event connected with the school in later life was the reception it arranged in 2004 on my receiving the Padma Shri. My relative, who was like an elder brother to me, Shankarettan (K.P.C. Shankaran Bhattathiripad) was the person who persuaded me to find time for this reception. In the event, I was overwhelmed by the affection showered on me. The programme was elaborate with speeches, interaction with students, Chenda Melam, caparisoned elephants etc. The programme was a mixture of serious business and celebrations. The main organizer of the event was the famous Peruvanam Kuttan Marar who himself received Padma Shri few years later. In addition to his very well known artistic pursuits, he was then employed in the school. A large number of my relatives, friends and former colleagues were present at the function. The main felicitation function also turned out to be a celebration of plurality. The school management had by then acquired a rightist tinge. The main speakers were C.K. Chandrappan, MP, K.P. Rajendran, MLA and Therambil Ramakrishnan, MLA and then speaker of the Kerala Assembly. Chandrappan was my old colleague and leader in the student movement, who rose to become the Secretary of the Kerala Unit of CPI. Rajendran is the son of the legendary leader K.P. Prabhakaran and Karthyayini teacher, whom I knew well during my student days. He subsequently became a minister in a Left Democratic Front Government in Kerala. Ramakrishnan, a Congress leader, was my classmate at Kerala Varma College. The function concluded with a Chenda (percussion) recital by none other than Peruvanam Kuttan Marar. None of the accolades I received elsewhere could match the emotional content of this one I received at my school where I took my first step towards scholarship.

Kerala in a cusp of history

My first innings in Kerala was primarily during the 1950s. As I have mentioned earlier, that was a decade of great hopes and greater dreams. In a sense, it also marked the culmination of Kerala renaissance. The Kerala model was in the making. Simplicity was celebrated. Caste consciousness, though still strong, was on the wane. Commitment to egalitarianism was strong. Of course, everything was not hunky dory. There was widespread poverty. Food was in short supply. A substantial proportion of the population was illiterate, although literacy in Kerala was higher than in the rest of India. Remnants of the feudal past still remained. Yet, hope was the dominant sentiment in the society.

Decades later Kerala presents a different picture. Substantial prosperity is on display. Acute poverty remains only in a few pockets. To a great extent, food shortage has been eliminated, thanks primarily to the green revolution. The population is almost entirely literate. The human development indices of Kerala are envied by others. A large segment of the population has been empowered through egalitarian measures taken by successive Governments. This also meant that a larger proportion of the population fell prey to consumerism in Kerala than in other states. Thus, as an unintended result of social engineering, widespread empowerment engendered widespread consumerism. The consumerist frenzy seen in Kerala is sometimes frightening. The stability of a system based on equitable distribution of scarce resources is secure only as long as needs of individuals are limited. In fact, the characteristic feature of life in Kerala was simplicity in food, clothing, housing and in overall lifestyle. It is this feature, among other things, that made the Kerala model possible. Aggressive consumerism has now begun to damage the model. Excessive competitive populism has also not helped. The malaise of excessive dependence on the service sector for growth, continues. The economy of Kerala depends greatly on remittances from abroad, particularly from the Gulf. There are now doubts about the sustainability of such remittances. Many are concerned about the destabilizing effect of the presence of unorganized labourers from other states, in the periphery of Kerala society.

Casteism, religious fundamentalism, revivalism, superstitions etc., which were on the retreat, are in the ascendance now. Erosion of secular values and paucity of inspiring ideals and personalities appear to have driven people to excessive religiosity and caste-based consciousness. Group identities are often used primarily for aggrandizement. The shrillness of disputes involving religion and caste is matched by the ferocity of political discourse. The picture of Kerala that one often obtains from the media is that of a fractured society.

The state of the society is naturally reflected in the education scenario as well. Additional specific problems also exist. Private agencies have played a remarkable role in the education system in Kerala. However, private participation in education is different from the participation of the so called self financing institutions. The latter often, but not always, involves crass commercialism and promotion of sectarian interests. Two parallel systems appear to exist in the higher education system of Kerala. One is extraordinarily expensive and the other almost free. The expensive self-financing sector has decisive influence on the higher education sector. The evil of commercialization can be combatted only by opening up more avenues in the Government/aided sector. This is not possible if higher education is entirely free even for the well to do. In this context, the specific recommendations on the financing of education by the Education Commission headed by Ashok Mitra, a staunch Marxist, deserve serious consideration.

The record of Kerala in promoting literacy and universal school education has been impressive. The same cannot be said about higher education and research. Centres of higher education and research, particularly universities, should be centres of excellence. This has not been wholly true about all such institutions in the State. The quest for equity has not been matched by that for excellence. One wonders if excellence is interpreted as some form of elitism, which is unfortunate. Equity and excellence are two sides of the same coin. Both should be promoted simultaneously. It is my impression that failure to do so has adversely affected higher education and research in the State. Furthermore, steps introduced with good intentions to bring about societal oversight of higher education, have to an extent had the unanticipated consequence of meddling by interested parties in academic affairs. This also has perhaps adversely affected the quest for excellence.

The situation in Kerala as gleaned from the media and private conversations, evokes hope as well as despair. There are perhaps signs of metastability. Instances abound in history when short periods of metastability have led to drastic changes in the direction of development of nations and regions within a nation. I hope that the enlightened people of Kerala and the popular movements involving them, have the capacity to prevent any retrograde turn in the history of Kerala. In any case, Kerala appears to be ripe for a second renaissance, with particular emphasis on rationality, simplicity, and sustainability, to restore and further develop the secular egalitarian ethos of Kerala.

16

SECOND DIGRESSION ON FAMILY

I do not expect readers to be particularly interested in personal matters. However, my persona has been substantially influenced by personal relationships. To me, family is a huge network involving a large number of individuals, all of whom are in one way or the other important for me. At its core is the nuclear family, our parents and families of our siblings. The earlier digression brought the narrative more or less till the birth of our daughter Devi in Oxford.

Core Family

On returning to India during late 1977, we settled in a flat in Malleswaram, Bengaluru. After a few years, we constructed a house of our own in Malleswaram. Thus, we have been residents of this wonderful neighbourhood since 1977. On our return from Oxford in 1977, I straight away started working in IISc. Kalyani remained at home for a few months nursing the baby, before re-joining NAL. We then had an ayah brought from Kerala to look after the baby. After a great deal of churning within ourselves, we admitted Devi in the Santosh Baby Care Centre in the neighbourhood, when she was one and half years old. The Centre was run by Indu Row, whom all of us call 'Indu Aunty'. She has looked after the babies of many faculty members of IISc and other well known institutions. Eventually, Santosh Baby Care Centre became Devi's second home. Indu Aunty, her daughter Nandita, son-in-law Mohan and their children Pratiksha and Aneev, almost became members of our family.

Some of the earliest friends of Devi were from the Baby Care Centre and were also children of our colleagues in IISc or NAL. I particularly remember two of them, Sushma and Appu. Sushma is the daughter of Vidya (who was then working at IISc) and Shivaswamy. Appu is the son of our friend Sunil Poddar, who has already been referred to, and Uma. Sushma, a scientist, is

One side of the family in 1987.
Front row (L to R) : Vijayan, Kalyani, Swapna, mother, father, Sandhya, Indira, Vasudevattan
Standing (L to R) : Mini, Devi, Savithri, Surendran, Happy, Nalini, Ravindran, Vinod.

The other side of the family in 1988.
Sitting (L to R) : Kamala with Sandhya, Kalyani, mother, Karpagam, Sujatha, Sarita
Standing (L to R) : Vijay, Giri, Vijayan, Balu, Subash, Sundaresan, Prakash, Devi.

Vijayan and Kalyani at home with Devi. An old photograph.

Kalyani, Devi and Vijayan at mother's 90th birthday celebrations.

now settled in USA. Appu is a practising doctor. During 1977 to 1983, we lived in a first floor apartment in Malleswaram. The ground floor was occupied by my long time friend and colleague K.R.K. Easwaran, his wife Lalitha and children Anu and Tina. We have been close to the extended families of Easwaran and Lalitha as well. Tina is a couple of years younger than Devi. Occupants of the neighbouring block were Nirmala and Kishan Das and their daughter whom we all call Lovely. Lovely is of nearly the same age as Devi. Tina, Lovely and Devi were boisterous playmates. Tina now shuttles between India and USA. Lovely is better known as Vasundhara Das, the famous film star and musician. Over the years, Devi grew close to our colleagues, friends and students and their families. She of course established a wide network of her own friends.

Except for an initial short pre-primary stint in another school, Devi had her entire school education till the 12th standard in the Kendriya Vidyalaya (KV) associated with IISc. Education in KV has had considerable influence on her. Unlike elite private schools, the KV has students from all strata of society which strengthened her egalitarian ethos. She was an all rounder and was involved in a variety of activities at the school. In fact, when she left school, she was given the best outgoing student award for that year.

After leaving the school, she joined the BMS College of Engineering in the government quota, on the strength of her performance in the entrance examination. She continued to maintain her outgoing personality. After obtaining her B.E. degree, she decided to move to management. On the basis of the results of an appropriate entrance examination, she joined Chetana Institute of Management & Research in Mumbai in 1999. During her two year stay in Mumbai, she was a paying guest in Bandra. This was the first time she was living away from home. After overcoming initial adjustment problems, she enjoyed her stay in Mumbai.

Her graduation with the Master's degree in management in 2001 coincided with a slowing down in the economy. Consequently, her well laid plans for future employment in Mumbai did not materialize. She returned to Bengaluru and eventually got jobs in the city. She moved to Dubai in 2003 where she has been most of the time till 2019. On her own, she dealt with her personal problems with fortitude and dexterity. While in Dubai, she took time to do an MBA at SDA Bocconi School of Management, Milan, which is among the top management schools in Europe. A degree from Bocconi and her varied work experience stood her in good stead. In between she spent one year in Amsterdam working for Infosys. Her base, however, has all along been Dubai. After working in multinational companies like Glaxo Smith Kline (GSK), Nestle etc., she was with the Tamdeen group based in Kuwait. The work involved, among other things, setting up a tennis academy, an event venue etc. She enjoyed the work. To our delight, recently she relocated to India and is employed in Bengaluru.

My parents naturally were central to the core family. My indomitable maternal grandmother spent half the time with my parents and the other half with the family of her other daughter. She had great influence on us until she passed away in 1992 when she was well past 86. My father had a busy social life after his retirement from the Cherpu school as its Headmaster. The same is true about my mother. They travelled extensively, including to United Kingdom where my youngest brother was a practising surgeon. They helped their children and grandchildren whenever required. The help included some degree of financial support as well. My father was 89 when he passed away in 1999. After my father's death, it was difficult to maintain the establishment at Cherpu. Half of the two acre compound had already been disposed of when father was alive. The old house where all of us children grew up and where grandchildren spent substantial periods of their childhood, was in a dilapidated condition. It had to be demolished. Much of the one acre compound in which the house stood was bought by nephew, Happy, and niece, Mini. A small area has been retained by my youngest brother Surendran. After father's death, mother lived with my brother Ravindran and his wife Nalini at Farook, till her death at the age of 93 in 2016. She was reasonably healthy except in the last year of her life. Although the house at Cherpu where my parents lived and all of us grew up was demolished, it is still green in my memory.

As mentioned earlier, my sister Indira and her husband Vasudevettan spent most of their lives in and around Tripunithura near Kochi. They have three children, called Vinod, a boy born in 1966, Mini, a girl born in 1967 and Happy, a boy born in 1970. They were the first set of grand children for my parents. My brothers Ravindran and Surendran and I naturally doted on our niece and nephews. Vinod and Happy did engineering and Mini did graduation and post-graduation in medicine. Vinod spent most of his professional life in the Gulf. He married Uma, a wonderful person who to us has been a niece rather than a niece-in-law. They have two sons Unni and Aniyan, who are now at the threshold of their youth. Mini, apple of our eye, is married to Santosh whom we are very fond of. Santosh is a senior officer of the Reserve Bank of India. Mini is currently practising in Apollo hospital in Navi Mumbai. They have two children, Manu and Suryan, both of whom are now embarking on their independent careers. Happy married Manju, a person very close to us. They have a school-going daughter, Arya. Happy spent most of his professional life in Pune. He, along with family, has now relocated to Thrissur.

Ravindran, whom we call Aniyan, and Nalini are well settled in Farook, near Kozhikode. He has retired from Farook College and Nalini from a school in the neighbourhood. The two have been the mainstay of the family and have helped all of us. All their nephews and nieces including Devi, treat them as if Aniyan and Nalini are their own parents. The feeling is amply reciprocated.

Surendran, called Kunjaniyan, and his wife Savithri are distinguished medical practitioners. After returning from U.K. with a FRCS from

London and another from Edinburgh, Kunjaniyan started his practice at Irinjalakuda, near Thrissur. Savithri also worked in the same hospital. In the early 1990's they moved to Sree Uthradom Thirunal hospital, Thiruvananthapuram where Kunjaniyan was appointed as the chief surgeon. Savithri joined the same institution. When Kunjaniyan was thus at the threshold of great career, he had a severe stroke in 1993 that ended his career as a surgeon. He faced the tragedy with great courage and fortitude. He continued to work, now as a specialist in radiology and imaging. Savithri developed into an outstanding gynaecologist.

Kunjaniyan and Savithri have two girls, Swapna and Sandhya. They were for a long time the youngest in the family and we are all very fond of them. Swapna was born in 1981 in Kerala just after Kunjaniyan left for the U.K. to work and pursue higher studies. Savithri and Swapna then joined Kunjaniyan in the U.K. where Sandhya was born in 1983. The family returned to India in 1986. Swapna became a dentist and Sandhya a speech therapist. Both of them are married into families well known to us. Swapna and her husband Amit are settled in the U.S.A. and have two children, a girl, Anisha and a boy, Kunju. Sandhya and her husband Rijesh are stationed in the U.K. They have two boys, Rohan and Krish.

The relationship within the core family goes well beyond the prosaic outline given above. All of us converged on the Cherpu house frequently, together or separately. My parents periodically visited us in Bengaluru along with one set or another of the nephews and nieces. We have had frequent interactions with my brothers and sister. I made it a point to visit the residences of my nephews and nieces, in different parts of India and abroad, until I became physically incapacitated. The core family has been a great support to me, especially in times of difficulties. The Cherpu group in WhatsApp, to which all of us belong, has now added to the coherence of the family.

We continued to visit Kalyani's parents at Chennai after we came back from Oxford in 1977. Within a few years, they left for the US to live with Kalyani's elder brother Balu. We did not meet her father subsequently as he passed away in 1983. Kalyani's mother lived until she was 95 and passed away in 2011. We and Devi have visited her in Balu's house. She also has visited us in Bengaluru a couple of times. Although we met only infrequently, she was an important presence in our lives.

Kalyani's younger brother Giri also left for US in the early 1980s. Another younger brother Sreedhar died prematurely in 1983. The only person in Kalyani's side of the family left in India was Karpagam, her elder sister. Karpagam had married Sundaresan, a computer specialist, in 1965. They spent most of their time in New Delhi where Sundaresan worked as the head of the computer division in DCM for a long time. He then turned a freelancer. Karpagam and Sundaresan have three boys, Subash, Prakash and Vijay. All of them graduated from IIT Delhi in computer related areas. We have visited them in Delhi and they also visited us in Bengaluru. In addition, I was a frequent visitor to their house during my trips to Delhi. Unfortunately, Sundaresan passed away at a comparatively young age in 1993. By then, Subash and Prakash had already left home for higher studies/jobs in the US. Vijay was still a student. That was the time when my trips to Delhi had substantially increased in frequency. I used to make it a point to visit Karpagam and Vijay whenever I went to Delhi. Eventually, Vijay also went abroad. Karpagam now lives with Vijay, his wife Aarthi and daughter Neha in Toronto. We have been close to Subash and Prakash as well. Subash, his wife Indu and daughter Priya are settled in the Silicon Valley. Prakash, his wife Shanke and children Bobby and Pari are also settled in USA.

We have a very warm relationship with Balu and his wife Kamala, although we meet them only infrequently. During most of his career, Balu taught in Morgan State University. He has been very active with community affairs. He has three daughters. Sujatha, Sarita and Sandhya, all of them well settled in the US. Our interactions with Sujatha, her husband Reuben and their daughter Manavi have been extensive.

Bits of family in Bengaluru

My cousins on both sides have been dear to us. One of them, Sreekumari, the youngest daughter of my mother's younger sister, came to Bengaluru after marriage around 1980 and settled here. Sreekumari is considerably younger than me. Her husband Damodaran who came from a family known to me worked in BMS College. Sreekumari herself was employed in Federal Bank. Needless to add, Sreekumari, Damodaran and their daughter Ramya have been very close to us. We were introduced to Ashtamurthy (Kunjunni) and his wife Savithri from a family in Kerala well known to me, by Sreekumari and Damodaran. Now we count them among our relatives.

Yet another set of relatives settled in Bengaluru with whom we have had constant interactions belong to the erstwhile royal family of Mankada, near Palakkad. My distant cousin, Indira, and her husband Omanakuttan were already in Bengaluru when I arrived here in 1963. Indira is of the same age as myself and I have known her well in Kerala. They have two sons, Rajesh and Aneesh. Omanakuttan unexpectedly passed away in 1971 and Indira and her children went back to Kerala. Our relationship with Indira's uncle, whom we call Kuttammama, and his sister Subhadroppa have been very close. Kuttammama married another Indira and they have two boys. That family returned to Kerala in 1980s. Subhadroppa's husband K.C.K.E. Raja, whom we call Kuttiettan, is a member of the large Kozhikode royal family. Subhadroppa, Kuttiettan and their son Vinod and daughter Shailaja have been in practical terms our closest relatives in Bengaluru. I have already referred to our relation with Indu Aunty and her family.

I have many younger relatives living in Bengaluru, temporarily or permanently. One of them whom we meet somewhat frequently is Anil (Anu Cotton), the son of my cousin Radha. Over the years, we have grown close to Anu, his wife Asha and their son Kunjunni. To my great joy, Aswathy, a grand niece of mine from a different lineage of our joint family, joined IISc for research in 2013. Her father Unni is dear to all of us. Unni's father, Valiya Neelandettan, has been the oldest male member of the joint family, after my father. I joined the Ph.D. programme of IISc in 1963 and another member of the family, Aswathy, joined the programme exactly half a century later! She married a fellow student, whom we call Aniyan.

We have been close to the families of many of our teachers, colleagues and those whom I have mentored. Including my Ph.D. students and post-doctoral fellows, I have been involved in mentoring close to a hundred scientists. I refer to them collectively as students. They and their families have been very close to us. I often say that I have one daughter and a hundred students!

The anchor

In nuclear families, the spouse is the main anchor in one's life. This has been more than true in my case. Kalyani has been with me through thick and thin for more than half a century. It is often said that there is always a 'surprised' woman behind a successful man. I do not know whether she is surprised, but she has always been behind me or rather, side by side with me. During the prime of our lives there has been considerable pressure on us, as both of us were working. After her career came to a successful completion, we decided to travel together. By then, Devi was also on her own. We travelled together all around the world, particularly when I was the President of INSA. Not long after my term as President came to an end, my physical disabilities started. Since then she has been stuck with me at home, involved in looking after me.

Kalyani came into our family from a comparatively different background. From the beginning, she earned the affection and respect of all family members. Now nobody can even imagine that she came from a different background and spoke a different language. She is a matriarch of the core family. My students, colleagues and their families have been very close to her. She has been at the apex of my academic joint family. I depended on her when I was healthy and now I depend on her all the more when I am physically disabled. I recall Pearl S. Buck, the Nobel Prize winning author, mentioning in one of her novels that love is like a strong silver thread, while marriage is like a web, equally strong but with a large number of strands. I have been fortunate to have a strong silver thread as well as a strong web.

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MOTOR NEURON DISORDER, WINDING UP WITH ADDED EMPHASIS ON TB PROTEINS

The senior scientist P.R. Pisharoty used to say that we are only entitled to the biblical life span of three scores and ten years. The rest is bonus. At 70, I was reasonably healthy and led a hectic life. In fact, I looked much younger than my age. Once, in a party after a CSIR Society meeting, Samir Brahmachari introduced me to Anand Mahindra, as his teacher. Mahindra asked me what I ate to look so young!

My 70th birthday fell in October 2011. In September, I made a hurriedly arranged trip to Rome with ease to participate in an ICSU meeting. In October, my birthday celebration was organized in a traditional manner in Kerala by Aniyan. Later in the month, Shekhar Mande and Sankaranarayanan organized a well attended symposium in Hyderabad in my honour, which culminated in a grand party cum felicitation function at Taramati Baradari. Still later in October, Kalyani and I went to Beijing to attend the Biophysics Congress. In addition to actively participating in the Congress, we also did a great deal of sightseeing. I recall that we climbed 484 steps on the Great Wall effortlessly. After returning from Beijing, Kalyani and I went to Cape Town in November, where I attended a meeting of the Advisors of ICGEB. After the meeting, we stayed on for a couple of days for sightseeing and had a hectic time. In addition to locations in Cape Town, we visited interesting places in the neighbourhood including the Cape of Good Hope, again without any indication of undue tiredness.

Progression of the disease

The 60th birthday of Samir Brahmachari was celebrated at the V.P. Chest Institute, Delhi, on January 1, 2012. I felt a sense of instability when

Vijayan and Kalyani at the Great Wall of China during the 2011 Biophysics Congress in Beijing.

Oxford friends together again in Auckland in 2012 to celebrate Ted baker's 70th birthday. Guy Dodson is in the middle. Standing (L to R) : John Cutfield, Tom Blundell, Rod Hubbard, Ted baker, Heather Baker, Sue Cutfield, Kalyani, Eleanor Dodson, Vijayan.

I was coming down a staircase in the building. I did not take it seriously. In February 2012, Kalyani and I went to Auckland, New Zealand to participate in a symposium to honour Ted Baker on his 70th birthday. Our idea of sightseeing in a city has been to walk around the place on our own. We started doing the same in Auckland which Kalyani was visiting for the first time. Soon, I developed severe pain in one of my ankles. The pain persisted when we visited Sydney, Australia, on our way back. That was when we realized that there is a serious problem with my legs. Incidentally, the trip to Auckland and Sydney turned out to be our last trip abroad.

To start with, the problem was with my left leg which led to my dragging that leg while walking. In course of time, the right leg also began to become unstable. A series of consultations with medical doctors ensued. Padma Srivastava of AIIMS persuaded me to get thoroughly examined under her supervision. In 2013, Kalyani and I spent a few days at AIIMS, thoroughly looked after by Padma, her colleagues, Tej Pal, Jagannathan and others. Satish Chandra, the then Director of NIMHANS, Bengaluru, also took considerable interest in me. Kalyani and I spent a few days in 2014 at NIMHANS as well. In addition to Satish Chandra and his colleagues, my grand student B. Padmanaban, who is a senior faculty member at NIMHANS, and his family were also in attendance looking after us. Furthermore, I was also treated by the well known Ayurveda physician G.G. Gangadharan who was then at the Institute of Ayurveda and Integrated Medicine (I-AIM), Bengaluru. We spent a couple of weeks each on two occasions at the Institute, undergoing different kinds of treatments. In my interaction with doctors, I was overwhelmed by their kindness to me. In the course of my illness I had occasions to consult many other doctors as well. I have also been in touch with P.N. Tandon, a doyen among neuroscientists.

Neurological disorders are difficult to accurately diagnose. Mine was eventually diagnosed as Motor Neuron Disorder (MND) which is also called Amyotrophic Lateral Sclerosis (ALS). This is the disease that Stephen Hawking suffered from. As indicated earlier, my disability started with legs. First, I could walk unaided, with some difficulty. Then I began to use a stick, then a walker and then a rollator. By the time Gopal organised an enjoyable function in honour of me on my 75th birthday at a resort near Bengaluru in October 2016, I was in a wheel chair. Happily, the function was attended by many of my friends, former students and present colleagues, including G. Padmanaban and A. Sridharan. At that time, my upper limbs were functional and speech intact. Despite these disabilities I have been carrying out my professional responsibilities including attending meetings in Delhi. INSA had made special arrangements in a guest room for my use.

We did some travel in 2016. Since then, we stopped travelling outside Bengaluru. My upper limbs began to weaken. Eventually, I got to a stage where I cannot write or use the computer. By 2018, my head began to droop and speech began to slur. There have been changes in the lifestyle also. In addition to Kalyani, there are now three persons to look after me, in a relay. My students had earlier presented a speech recognising software for my use. With impairment of my speech, I could not use that software effectively. My mind and intellectual capabilities remained intact, even when normal functioning became difficult on account of the inability to use hands and the impairment of speech. Kalyani, Devi and my Secretary, Pankaja, to whom reference has been made earlier, and my close colleagues can still follow me with some difficulty. In the course of the progression of my disability, Devi has been arranging to provide appropriate gadgets. She also spoke to Balki and R. Govindarajan, the then Chairman of the Supercomputer Education and Research Centre at IISc, enquiring if they can be of help to me. Govindarajan in turn contacted Pradipta Biswas of the Centre for Product Design and Manufacturing (CPDM) at IISc, who is an expert in eye-tracking. Pradipta and his students have developed an eye-tracking system for me. I practice on it, mainly with the help of Pradipta's student Kamal and my student Anju.

Despite my enormous physical disabilities, I am enabled to remain functional on account of the wonderful support system that I have. As indicated earlier, I anchor myself on Kalyani who is with me for almost twenty four hours. Devi visits us very frequently and does all that she can to help me and Kalyani. Members of my extended family, relatives, former students and colleagues visit us frequently. Gopal is the mainstay of my professional life. My lab is almost an extension of my home. My students, post-docs and assistants, are ever-ready to help me. As mentioned earlier, Pankaja looks after my requirements with diligence. Fortunately we have a set of care-givers who work with commitment and compassion. I have already referred to the kindness I have received from medical doctors. Riluzole (also known as Rilutor) has helped some MND patients. The medicine is not commercially available. However, Sun Pharma manufactures this medicine and supplies it free of cost to patients. I have also been a recipient of this munificence. I recall the earnestness with which the timely supply of the medicine is ensured by the distributors, particularly Shubhankar Sarkar. I have undergone many different types of treatments. In all of them, I have been overwhelmed by the kindness shown by those who administered them. The treatments and the emoluments of the care-givers put together cost a great deal of money. Fortunately the expenses have not been a major problem for us, thanks to our savings, two pensions and the generous emoluments associated with two of my post-retirement assignments. I shudder at the plight of patients who are not sufficiently financially endowed with.

As I dictate these lines in late 2019, I am still going on working as well as I can. It is easy to give up, but as Jawaharlal Nehru has quoted from Robert Frost,

'The woods are lovely, dark and deep,
But I have promises to keep …
And miles to go before I sleep..
And miles to go before I sleep'

Winding up organizational responsibilities

Over the years, I have been involved in many different activities, nationally and to an extent internationally. In all of them, my base has been IISc, particularly MBU. I was absolutely certain that I would continue at MBU after retirement only if my colleagues wanted me to do so. As many others have done, I could have made my post retirement arrangement elsewhere, although it was appropriate to remain in MBU for the sake of continuity. I used to have detailed discussions in this regard whenever there was a change of guard in MBU or whenever my position changed (Distinguished Biotechnology Professor, DAE Homi Bhabha Professor, INSA Albert Einstein Professor, NASI Senior Scientist), with the Chairman and other senior colleagues. At the time of my formal retirement, Surolia was the Chairman. He was succeeded by M.R.N. Murthy. Dipankar Chatterji was the Chairman when my Honorary Professorship came to an end. Dipankar was succeeded by Raghavan Varadarajan. On each occasion, the Chairman and other colleagues wanted me to continue to work in MBU and help and advise them. They also made appropriate arrangements to enable me to continue with my work, with B. Gopal at the centre of the support system. By the time N. Srinivasan took over as the Chairman of MBU, in late 2018, I had already decided to conclude my career within the time frame of a couple of years.

From about 2010, my effort was to wind up my activities one by one. The most important element of my activities is undoubtedly the X-ray lab of MBU, from which much of the macromolecular crystallography in India radiated. M.R.N. Murthy was expected to succeed me as the head of the lab. However, he decided to withdraw from full time research to pursue his interest in educational programmes. I respected his decision. However, I was anxious, but not for too long. Young Gopal rose to the occasion and stepped in with the role as my successor. The ongoing phase of the DST support for the X-ray facilities under the IRPHA programme was scheduled to come to an end in 2017. My colleagues wanted me to lead the efforts for obtaining support for one more five year phase although, quite appropriately, Gopal would be formally designated as the Principal Investigator. Our performance over the decades has been recognized as excellent. However, the new SERB system was in a flux. I was concerned as to how to maintain continuity. I contacted R. Brakaspathy, the then Secretary of SERB, whom I knew well during the years of my involvement with SERC. To my great relief, Brakaspathy assured me that they would not let us down in any circumstance, in view of the importance of the Facility. He stuck to his word. As always, Praveen Kumar Somasundaram was by our side to help us. The new phase was sanctioned and started in 2017. Gopal is now running the Facility efficiently with the support of all of us.

There was a time when macromolecular crystallography activities in the country relied a great deal on my support and guidance. That situation has completely changed. We now have in India a several hundred strong macromolecular crystallography community with a number of well established leaders at the helm. Yet I continued to lead a couple of major initiatives. Initially, I have been the driving force behind arranging our access to the Grenoble synchrotron facility and setting up an Indian beamline under the leadership of D.D. Sarma at Elettra in Italy. I have been from the beginning the Chairman of the two concerned review committees. I have now stepped down from the positions. I chaired the Committee concerned with the Grenoble facility for the last time in 2016. The meeting was held, for my convenience, in Bengaluru. I continued to chair the committee on Elettra beamline till 2019. The last meeting of the committee was also held in Bengaluru. I was deeply involved with Indus 2 at Indore, especially when the National Committee chaired by S.K. Sikka and myself was operational. We could establish splendid relations between those who ran the facility and the user community, when P.D. Gupta was the Director of RRCAT. I would have loved to continue my association with Indus 2, but ill health prevented me from doing so.

After the revival of the Indian Biophysical Society around 1990, Girijesh Govil and I used to play an unobtrusive supervisory role in its affairs. I, almost imperceptibly, withdrew from that role a few years ago. The Society is now in robust health. Indian Crystallographic Association is younger and was established in 2001 with myself as the Founder President. I used to be consulted by the concerned people on the affairs of the Association, particularly on the change of office bearers every three years. The last change took place in 2019. The Association is also in robust health. My major roles in IUPAB and IUCr were completed before I assumed the Presidentship of INSA. After relinquishing the Presidentship of INSA, I was involved, among other things, in the Inter-Academy Ethics Committee which resulted from an initiative originally taken by Obaid Siddiqi. The composition of the Committee was changed a couple of years ago at the request of incumbent members, as we felt that a generational change was then necessary. My involvement with international organizations tapered off over the years.

I slowly withdrew from the advisory bodies of institutions. The last positions I relinquished were the chairmanship of the Scientific Advisory Committee of NII and that of the Research Council of IICB, both in 2015. As my health deteriorated, I began to decline invitations to different selection committees. One by one, I withdrew from committees associated with grant giving agencies. In this context, the last position I relinquished was the Chairmanship of the Subject Expert Committee on Life Sciences of the FIST programme, a position which I continuously held from 2006 to 2015. My last visit to Delhi was to attend a meeting of FISTAB, the apex body of the FIST programme then chaired by S.K. Joshi, which followed the last meeting of the Expert Committee on Life Sciences under my Chairmanship in Bengaluru.

I had wound up my organizational responsibilities substantially by 2015 and completely by 2019. What remained was to wind up my scientific research. By late 2019 my small research group consisted of three doctoral students, all co-registered with Gopal and me, one very close to submission of the thesis, three post-doctoral fellows and Pankaja as my Secretary and general administrator. Very recently, Lalitha joined me to share the responsibilities of Pankaja. Among the students, N. Sivaji works on lectins. He interacts with Suguna and Surolia as well. The other two, Anju Paul and Prateek Raj, and the three post-doctoral fellows, Sri Kalaivani, Sibi Narayanan (recently replaced by Sriram Srinivasa Raghavan) and Karthik Selvam, work on mycobacterial, mainly TB, proteins. They interact with Gopal and to an extent with Umesh Varshney. Financial arrangements for the work have been made till the middle of 2021. The current projects should be completed by that time. If my health fails before that, Gopal has kindly agreed to step in and complete the projects, with some help from Suguna in the case of lectins.

Final lap. Further rendezvous with TB proteins

As mentioned earlier, I wound up two of my major research programmes around the time of my formal retirement. One had to do with supramolecular association involving amino acids and peptides and its implications to chemical evolution and origin of life. The second was concerned with water mediated transformations, with special emphasis on protein hydration and its consequences. Both the programmes addressed fundamental issues and I enjoyed pursuing them. However, the only senior person involved with the programmes was myself. It was not desirable to continue with major programmes at an advanced age, when there is no fallback position. I continued, still continue, with the programmes on lectins and mycobacterial proteins.

In addition to yielding interesting scientific results, the lectin programme has had a decisive impact on the development of macromolecular crystallography in India. We continue working on lectins, now with emphasis on those from mycobacteria and archea. However, the main thrust of the laboratory is on mycobacterial proteins. In addition to pursuing our own researches, I made every effort to encourage structural work on TB proteins by others and to network with them. Currently, structural biology studies on such proteins are being carried out in about a dozen laboratories in India. Among the structures of TB proteins determined globally, more than 10% have emanated from India. Indeed, Indian contributions form an important component of the global efforts on the structural biology of TB proteins. These contributions have not only advanced our basic understanding of the pathogen, but also have provided a platform for structure-based inhibitor design, as a step towards drug development.

It was now time to consolidate our thoughts on the work in the area and its future directions. As I have done on earlier occasions, I wrote an article on the subject in *Current Science* (*Curr. Sci.* **108**, 775-777, 2015). I cannot do better than to quote selectively from that article.

"The long-term primary objective of structural studies, as indeed of biochemical and molecular biology investigations, on microbial pathogens is to understand the basic biology of the organisms. With the advent of antibiotics, it was hoped that infectious diseases could be brought under control. However, that was not to be. The organisms rapidly developed resistance to existing drugs and there is need for developing new drugs, against which again resistance is likely to develop. Pathogens like ***M***. *tuberculosis* have been with humanity for millennia and they are unlikely to go away in a hurry. Therefore, we need to wage a long-term battle with them. For that, we need to understand the organisms as well as we can.".

"In addition to serving the long-term purpose of understanding the basic biology of pathogens, fundamental research, including that involving structural biology, can form a basis for applications such as drug development. It is often good fundamental research and a prepared mind that lead to applications.................. The availability of the three-dimensional structures of a number of important proteins from a pathogen provides a platform for the structure-based design of inhibitors as a first step in drug development. .... In the total scheme of things, the design of inhibitors, though intellectually challenging, is the least expensive component. That also does not call for elaborate organizational structures and is in the nature of normal laboratory research effort."

Need for new or modified paradigms of rational drug design

"Rational drug design, including that based on structural information, generally involves identification of a validated target and then discovering through screening or designing a small molecule that interferes with its function. This general approach has yielded rich dividends, but has probably entered the phase of diminishing returns. Perhaps, a more holistic approach is now called for. The practice of combination therapy for TB, for instance, is a step in that direction. In this instance, a few targets are being simultaneously targeted. Going one step further, it is desirable to adopt a holistic approach at the early stages of drug design itself."

"The above considerations lead to the suggestion of a plausible approach involving structure-based design of inhibitors. The approach involves the design of inhibitors for a large number of important proteins from an organism, without being too concerned about the essentiality of each individual protein. The choice of proteins could be left to the concerned investigators, without imposing restrictions on the basis of the currently prevailing paradigm. Large-scale design of inhibitors is now technologically feasible and is not far too expensive. Inhibitor design involves biochemistry/molecular biology, structural biology, bioinformatics and organic synthesis. Efforts in each of these areas are becoming easier by the day.......... The crux of the approach is to produce baskets of different inhibitors to choose from. Once a few are chosen for further efforts at drug development involving simultaneous targeting of several proteins, it then becomes a different ball game requiring large organization and funds. That phase does not come under the purview of the present discussion. In any case, drug development is not the only use of inhibitors. They are indispensable tools in biological research. Therefore, designing of inhibitors is an intrinsically worthwhile exercise, quite apart from its utility in drug development."

Guided by the above approach, we initiated some preliminary exploratory studies on design of inhibitors against a couple of TB proteins. Drug development against TB would necessitate a long term programme involving perhaps hundreds or thousands of crores of rupees and hundreds of people. No frontline drug against TB has been developed during the last several decades. That illustrates the magnitude of the problem. However, we cannot afford to give up. Endeavours to develop drugs against TB should continue, especially in a country like ours. Our current efforts can only be considered as baby steps in that direction. We may succeed or falter. In any case, I hope that our preliminary exploratory work would contribute to developing a culture of structure-based inhibitor design against TB proteins in India. As happened in the case of macromolecular crystallography and, more recently, in relation to structural biology of TB proteins, it is my hope that a strong networked community engaged in structure based development of drugs against microbial pathogens, especially the TB bacillus, would emerge in the country. I am conscious that unlike in the case of my earlier initiatives, I would not have time to take the present initiative to a logical conclusion. However, I have the satisfaction of having made a preliminary attempt to initiate the effort.

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LOOKING BACK

As in the case of most others, more than one identity coexist in me. My strongest identity is as an Indian scientist. Then I have a significant international identity. Having lived in Bengaluru during most of my adult life, I have a Kannadiga/ Bengalurian identity. Although I left Kerala when I was barely twenty, I have been engaged with the State in one way or another, throughout my life. Therefore, I have a strong Malayalee identity. I never felt any conflict among these identities; in fact, they have been complementary to one another.

During most of my career, I have been involved almost exclusively with science and its organization. I enjoyed my attempts at molecular match making and its implications to chemical evolution and origin of life. Different protein molecules, each with its own personality and characteristic features, have been my constant companions during the last few decades. However, love of science alone cannot explain my total commitment to work. India is the other element that contributes to the commitment. This is not only because India is my country but also because India has been among the down-trodden, particularly during the period when I started my scientific career in the 1960s. The Third World was then a reality and the main conflict in the world to a substantial extent was between the developed North and the underdeveloped South. One became acutely aware of this disparity while living abroad. On the sidelines of a scientific meeting in 1970, I recall a senior colleague taunting me that they (Americans) have been feeding us (Indians). That colleague was not typical of the members of the international scientific community. He was among the small minority whom we used to describe as 'Goldwaterish' (Goldwater was the extreme rightist Republican candidate who lost to Lyndon Johnson in the 1964 American Presidential election). However, the taunt was correct. India was then woefully short in food production. The shortfall used to be filled up with surplus American wheat procured under the somewhat humiliating

PL480 scheme. Our enemies often used to treat India with contempt while our friends sometimes tended to be condescending.

I, like many other Indians, reacted with a dose of positive nationalism to the scenario outlined above. The thrust of this nationalism was the urge to contribute to the development of India. There was no element of jingoism in it. This nationalism has been in perfect harmony with my internationalism. Our international contacts have been very dear to us. Our main scientific mentor has been Dorothy Hodgkin, a great English woman and leader of global science. She was almost like a mother to Kalyani and me. Many of our close friends and well wishers are from abroad. They applauded and appreciated my pioneering efforts in macromolecular crystallography in India. Thus, my nationalism has not been anti anybody, but only has been pro Indian.

The situation is now very different from what it was in the 1960s. The change stuck me particularly during my Presidentship of INSA when I was involved in many high level international interactions. India is now taken seriously and our voice is listened to with respect. India's involvement in bilateral and multi-lateral scientific agreements, is sought also for the Indian funds that they bring in. All the same, India still remains a developing country. The centre of gravity of science and much else still remains in the West. We have a long way to go before we can deal with the advanced countries on equal terms. Therefore, the kind of nationalism I espouse is still a positive force.

In 1947, the people of India inherited a country devastated by a couple of centuries of ruthless colonial exploitation and ravaged by partition and the communal holocaust that accompanied it. A substantial part of India was ruled by about 600 princes, providing an ideal setting for Balkanisation. It is a tribute to the acumen of the then national leadership and the sagacity of the people of India that the foundation of a modern secular democratic republic could be laid in the early years of independent India. Since then, India has made considerable progress in different spheres of activity, partly based on science and technology developed in India or adapted by Indian scientists and technologists. There are positive and negative aspects in the Indian endeavours in science and technology. Sometimes I feel that the positive features are not sufficiently appreciated. There has also been some diffidence about our competence to deal with high level science and technology. I recall the snide comments I used to hear when the first Satellite Launch Vehicle (SLV) was being developed by ISRO. There were naturally failures with the vehicle falling into the sea. Some people then used to derisively refer to SLV as the Sea Loving Vehicle. However, one can now see where ISRO has reached - the Moon and the Mars! Likewise, I remember some distinguished colleagues commenting that the light combat aircraft (LCA) would never fly. The aircrafts are now a proud possession of the Indian Air force. Nearer home, many colleagues used to discourage me from venturing into initiating macromolecular crystallography in India. When we had some early failures, they repeated their arguments as to how we cannot do it in India. Fortunately, I had many senior well wishers in India and abroad and a granting agency which stood by me with rock-like solidity. That enabled me to go ahead with my efforts. Presumably on account of the strides made by India in different spheres including science and technology, the present generation of Indians are more confident in dealing with the West than those in my generation have been.

Despite many difficulties and financial crunch, the organisational foundations of Indian science were laid under the patronage and active involvement of Jawaharlal Nehru, the first Prime Minister of India. Governmental support for science progressively increased till the end of 1980s. In fact, science in India made great organisational and technical strides in the 1980s. R and D funding improved substantially. In relation to my efforts, adequate funds were available for the first time to launch macromolecular crystallography studies in India. By the end of the decade, S and T expenditure in India rose to around 1% of the GDP.

The euphoria of the 1980s evaporated during the early and mid 1990s. Partly on account of financial compulsions and substantially because of idealogical predilections, the S and T expenditure precipitantly fell to 0.67% of the GDP. The Government gave the distinct impression of substantially withdrawing from the higher education and research sector. Appointments in many public funded institutions were frozen or curtailed. The ill effects of the actions of that period persisted for a long time. Many in the scientific community felt neglected or, worse still, rejected. The mood changed to a great extent after Atal Behari Vajpayee coined the slogan "Jai Jawan, Jai Kisan, Jai Vigyan", towards the end of the decade. Since then till now, the support for science and technology in India has hovered around 0.8% of the GDP.

S and T expenditure in India at 0.8% of GDP is abyssmally low. India used to be once described as the superpower of Third World science. That is no longer true. China is miles ahead of us for good reasons. For one thing, as indicated in Chapter 14, the S and T expenditure in China is now 6 to 12 times that in India depending on the way GDP is calculated. Furthermore, the structure of Indian science is to a great extent unequal to the challenges of modern scientific research. I have written extensively on the subject and I need not repeat the arguments and suggestions here. Another area of concern is related to the public perception of science. To a large extent, science has gone out of main stream national discourse. Spectacular technological achievements like Chandrayaan and Mangalyaan receive considerable attention, which is good, particularly because progress in the strategic sectors is wholly based on home grown science and technology. These achievements are a tribute to the robustness of Indian science and technology. However, much of science is unspectacular. Peaks occur only infrequently and they are built on the overall edifice of science. Everest exists only in the context of Himalaya. The overall effort should be to strengthen Himalaya. Everests are more likely to emerge from a strong Himalaya. Therefore, it is important for us to emphasize the need for supporting science as a whole. It is also necessary to educate the general public, opinion makers and the political leadership on the considerable contributions science and technology have made to the development of India.

As indicated earlier, the approach of many of us has been to take full advantage of the positive features of the system while trying to improve it. While doing so, I have been overwhelmed by the all round support and goodwill I have received from my elders, contemporaries, younger colleagues and individual bureaucrats. Although my primary preoccupation was with structural biology with special emphasis on macromolecular crystallography, I came to be engaged with Indian science as a whole. I particularly value the personal relationships I developed through these engagements. The relationships I developed through my limited engagements with international science, have also been valuable to me. What gave the greatest satisfaction to me in my career is mentoring of young scientists, all of whom have been very attached to me and my family. Most of those whom I mentored have done very well in their career. Some of them have scaled great heights and are among leaders of science in India and elsewhere. I also had the good fortune to be able to mentor an area of science as a whole.

A personal element was always present in my interactions with students, post doctoral fellows, employees and other colleagues. Results are important; human beings are equally or more important. This is the approach which Dorothy Hodgkin always adopted. Love and trust beget love and trust, and bring out the best in people. When dealing with people, it is important to be guided by compassion, commitment and competence, in that order. To be compassionate does not involve taking leave of judgement. One can be compassionate while at the same time cognizant of weaknesses of the concerned person. The effort should be to bring out the best in the person and not to unduly dwell on the weaknesses. In addition to those whom I have mentored, I have had very close and pleasant relations with the members of the larger scientific community. I am known to take strong positions on issues. However, I have tried to ensure that I do not personally attack individuals. Probably because of that, my relations with others in the community have been by and large very cordial, and indeed often intimate.

Although my activities during the past half a century have been almost exclusively centered around science and its organization, I have been very sensitive to the national and the international developments around me. My reactions to these developments are of not much consequence to my role dealt with in this narrative. All the same, it is appropriate to say that, like many others, I feel that we are living in a fractured nation in a fractured world, to an extent dominated by authoritarian tendencies and acute conflicts of interests. Inequalities are increasing at a rapid rate the world over, rendering societies potentially unstable. Discourses among individuals and different sections of society have become frighteningly fierce and personal. There has been progress and in general living standards of people are getting steadily better. However, the dream of an equitable world is fast receding. The paradigm of development followed by all nations is based on excessive consumerism leading to large scale environmental problems. Even the mood of a congenital optimist like me is dominated by forebodings. Science is not only a refuge from the harsh external realities, but also a means to deal with them. Furthermore, in a situation where science is substantially orphaned and does not form part of the main agenda of any political formation, it becomes the particular responsibility of scientists to protect and promote science. Science is an endeavour in which still rationality prevails and the discourse is primarily evidence based. Also, irrespective of the prevailing dominant political dispensations, science is a potent instrument for progress and societal transformations.

The role of science in societal transformations is very well recognized. There is also a civilizational aspect of science. Science involves an evidence-based approach to issues. That's what makes the global scientific community reasonably coherent in spite of national, political and economic diversities. Science also involves a celebration of excellence. For many of us, it is a way of life. I have enjoyed my life in science, with concomitant commitment to India and special emphasis on mentoring.

“Indian Science is poised for quantum leap in the coming decades through the commendable achievements in “strategic” sectors of the science.

The developed countries have now started discussing the name of India as a force to be reckoned in science. Thanks to the sanctions imposed by them during the initial post independence days, India was insulated from the know-how for basic science research as well as heavy industries. The foresightedness of the Indian political leaders, who stood for the advancement of indigenous strongholds in research, technology and industry is paying rich dividends.

Government is giving added thrust to basic sciences now. But autonomy to research institutions is mandatory for attracting and retaining talents. Bureaucratic meddling should also be minimized”.

—**Mamannamana Vijayan**

(Talking to the research scholars of MG university on the Performance, Promises and Problems of Indian Science, 18th June, 2010)

Science and technology constitute a pre-eminent tool to enhance the wellbeing of people. Science is also a way of life, an approach to problems and a celebration of excellence. Promotion of excellence is a hallmark of a healthy civilization. This civilizational aspect of science is of paramount importance. In addition to helping the material welfare of the human kind, science also helps lead us into that heaven of freedom “Where the clear stream of reason has not lost its way into the dreary desert sand of dead habit”.

In order to unleash the creative potential of Indian science, we need a vibrant, resilient and sensitive system which is less bureaucratic, less hierarchical, more autonomous and more participatory.

– M. Vijayan

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