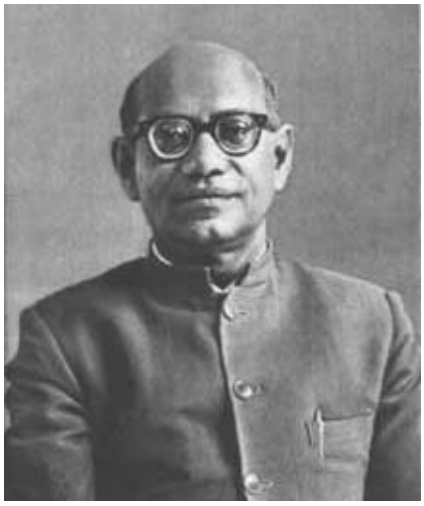
Bires Chandra Guha – Father of modern biochemistry in India*

I. B. Chatterjee and D. P. Burma

B. C. Guha lived through biochemistry, and biochemistry in India, especially modern biochemistry, could be equated to Guha. It will, however, be wrong to judge the personality of this unusual biochemist through biochemistry alone. Considering his humanitarian, social and political activities, the understanding of his character through his biochemical activities alone will be a complete failure and this unprecedented character has to be evaluated in all its totality. It should, however, be emphasized that he was entirely different from numerous talented scientists born in this country in the pre-independent era. There are numerous biochemistry departments created in the country just before and after his sad early demise. But very few biochemists are aware of one of the most important contributions of this great personality in biochemical education in our country. The report on Biochemistry in Indian Universities by the review committee appointed by the University Grants Commission in 1959 under his chairmanship is practically a bible for the biochemist community depicting the past, present and future of not only biochemical education but also its research activities. There were only a few biochemistry departments in the country at that stage, but evaluation was done for the past as well as their future activities. On the recommendation of the committee, biochemical education definitely got a boost in the country.

There is no doubt that the Indian Institute of Science at Bangalore created the first Chair of Biochemistry in India in 1921, but to some extent it may not be entirely true, as will be discussed later. This is not to deny the role of the Department of Biochemistry at the Indian Institute of Science, Bangalore, with its glorious past and present history. This centre has played the most important role in the development of biochemistry and even now occupies the pivotal position in biochemistry in India. The history of Biochemistry that is being written through the enterprise of History of Indian Science, Philosophy and Culture will naturally support it without any ambiguity. Unfortunately, in spite of its glorious achievements the department never tried to play the pivotal role in biochemical education as done in the University system, perhaps due to some restrictions in the management of the Institute. Attempts were made from time to time by one of the authors (DPB) to induce the department to take this leading role in the country and help to create similar centres elsewhere by setting the first example, but the department failed to provide the leadership in the development of proper biochemical education in the country.



Guha was not only a research worker, but also an educationist which is perhaps a situation somewhat lacking in this country and perhaps this has resulted in the impediment of growth of educational manpower. This is a matter of debate and can easily be brushed aside at the cost of the universities.

With this background let us now start with the early years of Guha, which will clearly indicate that Biochemistry was not only his love but a part and parcel of all his activities. He was born on 7 June 1904, at Mymensingh (presently part of Bangladesh). Guha's father's name was Rashbehari Guha Thakurata who held from Banaripara, part of Barishal at present in Bangladesh. He was the youngest of a large family of four brothers and four sisters. Guha was greatly influenced by his maternal uncle Aswini Kumar Datta, a well-known freedom fighter. He had to suffer for following the footsteps of his maternal uncle. The whole family was deeply involved in the struggle for independence. At that time the situation in the country was quite different from today and the younger generation born as British subjects, were ready to revolt at any cost to get freedom from British rule. From the very beginning of his educational career it was one of Guha's major objectives. It is unbelievable to conceive that at the age of eleven Guha was inducted in the revolutionary Jugantar Party, the nightmare of the British. In 1919, Guha passed his matriculation examination from Sri Krishna Pathshala and also I Sc Examination from the City College, both located at Calcutta. He stood second in the latter examination. He was admitted to the B Sc course in Presidency College, the topmost college in Calcutta. At that time he fully participated in the non-cooperation movement of Mahatma Gandhi against the British Government. As a result he was imprisoned for a month. At that stage Principal Barrow of the Presidency College advised him to leave the College. None of the colleges in Calcutta agreed to admit him in spite of the fact that he was one of the most brilliant students produced by Calcutta University. Fortunately, the St. Xavier's College finally accepted him and Mr Barrow was happy to provide the transfer certificate. In 1923 he passed Chemistry Honors Examination holding the first position in first class. Then he got himself admitted to the M Sc (Organic Chemistry) course at the University College of Science, Calcutta, where he again stood first in first class. Being a freedom fighter his sufferings did not end at that stage. He had to face adverse situations when certain appointments were concerned.

The next phase of his career was also equally challenging. He started his research career under the guidance of P. C. Ray, a famous chemist with an unusual personality. The latter lived a most austere life and tried to infuse the same spirit in the younger generation. As a chemist his primary objective was to develop small-scale chemical industries. He inspired the students not only to devote themselves to

*This article is written in honour of Late B. C. Guha on his birth centenary.

scientific research but also to start small-scale industries. Bengal Chemical and Pharmaceutical Works of Calcutta was the best example set up by him. This was to induce national spirit for economic development. It should be mentioned that in the British regime, manufacture of even a needle was not allowed in our country. P. C. Ray one of the most humanistic scientists produced in the country, chose his laboratory at the University College of Science and breathed his last there. He donated all his savings to the University College of Science. Guha followed his preceptor's steps while carrying out research under him. During his stay with P. C. Ray for one year, Guha published three papers: two on the varying valency of platinum with respect to mercaptonic radicals and one on the synthesis of condensed heterocyclic system.

After working with him for full one year, Guha was prepared to go to England with the Tata Memorial Scholarship and travelling fellowship. But an adverse report by the police led to cancellation of his passport. By the combined efforts of Sir Edward Greaves, the then Vice-Chancellor of Calcutta University and Acharya Prafulla Chandra Ray, he was finally provided the passport, subject to the condition that Sri Surendranath Mallick, member of the Indian Council in England would keep a strict eye on his movement while in England. He worked with two leading biochemists, Sir Jack Drummond of the London University and with the Nobel laureate Sir Frederick Gowland Hopkins, father of British Biochemistry at Cambridge and earned the degrees of Ph D and D Sc of London University.

We must divert here a little to understand what influence this training had on his career. P. C. Ray was the guiding star of B. C. Guha's early research career. Similarly, his experiences in the laboratories of Drummond and Hopkins led to a strong foundation of biochemical research, which was his life occupation. It was not only the influence of Hopkins himself, but association with several biochemists during his work in his laboratory which were of great help in moulding the future biochemists of this country. It will not be out of context if we give a brief background about the nature of research going on at that time in the laboratories of Drummond and Hopkins when Guha joined them. In 1912 Gowland Hopkins discovered the food 'accessory factors' which were later proved to be growth-stimulating vitamins. After the discovery of the food 'accessory factors', the experimental approach to nutritional problems was assuming an ever-increasing importance and the course of events was the era of individual vitamins. Both the laboratories of Drummond and Hopkins were vigorously engaged in discovering the individual vitamins. When Guha joined the laboratory of Drummond, he was assigned to isolate and identify the water-soluble vitamins present in the polishing of rice. Both in the Japanese Navy as well as Norwegian Navy, a high proportion of the sailors suffered for many years from beriberi, a condition now known to be a vitamin deficiency disease. The Dutch physician, Christian Eijkman of Utrecht University, the Netherlands, while working in Java in 1897, showed that the addition of rice polishing to the diet would ameliorate the beriberi. He produced polyneuritis, a primary symptom of beriberi, in chickens by raising them on polished rice. Other chickens given unpolished rice showed no symptoms. Funk[1,2] attempted to isolate the active principle of rice polishing that was responsible for relieving beriberi in pigeons and other animals, but he was not successful at that time. Guha started with full vigour to isolate the vitamin from water-extracts of both rice polishing as well as yeast. He measured the activity of the preparation at each stage of concentration by bioassay in deficient rats. Unfortunately, before he could purify the factor, Jansen and Donath[3] of Amsterdam succeeded in obtaining the vitamin (thiamine or vitamin B_1) in a pure crystalline form. In 1929 the Nobel Prize was awarded jointly to Eijkman 'for his discovery of the anti-neuritic vitamin' and Sir Frederick Hopkins 'for his discovery of the growth-stimulating vitamins'.

Guha then switched over his thesis work to the isolation and identification of a heat-stable vitamin present in the rice polishing. In 1920, A. D. Emmet and G. O. Luros reported that autoclaved yeast no longer contained the antiberiberi factor (vitamin B_1) but did contain a substance that promoted growth of rats on certain synthetic diets, which was later found to be riboflavin or vitamin B_2. Guha did lot of work on vitamin B_2, but he was not able to isolate this vitamin in pure form during his short stay in Drummond's laboratory. Pure riboflavin was later isolated from milk in 1933 by R. Kuhn and his co-workers. During his stay in England, Guha published ten papers on vitamin B_1 and B_2 in the then prestigious journals[4–13].

After working in Drummond's laboratory, Guha moved to Cambridge to work in Sir Frederick Gowland Hopkins' laboratory. The Cambridge laboratory, with Hopkins as its leader, was at the peak of its glory when Guha joined in 1930. There was a galaxy of bright visiting scientists from different parts of the world, including England, Europe, USA, and Japan. In fact, seldom had there been such a gathering of scientific talent and concentration of creative scientific activity in one place in the history of science. To name a few, are Albert Szent-Györgyi, C. G. King, C. A. Elvehjem, A. C. Chinball, F. G. Young, Joseph Needham, Malcolm Dixon, L. W. Mapson, L. J. Harris, N. W. Pirie, Robin Hill, E. Baldwin, M. Stevenson and J. B. S. Haldane. The name of Haldane, the eccentric scientist of unusual talent and far sight is worth mentioning here, because Haldane eventually chose this country as his home and died on Indian soil.

Guha spent most of his life working on nutrition and vitamins of which ascorbic acid played the most important role. Guha's interest in vitamin C originated from his association and discussions with Albert Szent-Györgyi at Cambridge. In 1927, Szent-Györgyi, a Hungarian scientist, came to work in Hopkins' laboratory for a short period on a problem with quite a different objective: isolation of a redox substance present in animal and plant tissues. The discovery of vitamin C by Szent-Györgyi was accidental. While extracting and concentrating some redox compound from ox adrenal glands, he isolated some sugar-like crystals about which he was quite ignorant. One would realize this from the title of his paper: 'Observation on the function of peroxidase systems and the chemistry of the adrenal cortex: Description of a new carbohydrate derivative', published in *Biochem. J.*[14]. He was so ignorant of the nature of the carbohydrate derivative that he first named it ignose (ign for ignorance and ose for sugar) and later godnose (God knows). But the editor of the *Biochemical Journal* objected. Very quickly the structure of the carbohydrate was elucidated in collaboration with Haworth at Birmingham (arranged by Hopkins) and the alternative name given was hexuronic acid (hex = six). During the same period (1928–1931), Charles Glen King

of the Columbia University of USA isolated vitamin C from lemon juice and it was observed that hexuronic acid and vitamin C were identical. Szent-Györgyi had no idea that hexuronic acid might turn out to be a vitamin. It is ironical that Szent-Györgyi isolated vitamin C without doing a single animal experiment. In the words of Szent-Györgyi himself: 'I was not acquainted with animal tests in this field and the whole problem was, for me too glamorous, and vitamins were, to my mind, theoretically uninteresting. Vitamin means that one has to eat it. What one has to eat is the first concern of the chef, not the scientist'[15]. In any case, Szent-Györgyi received the Nobel Prize in 1937 for his discoveries concerning biological oxidation processes with reference to vitamin C. It is worth mentioning that Guha with his expertise in bioassay, which he learnt in Drummond's laboratory, helped Szent-Györgyi quite a lot to understand the nature of the anti-scorbutic property of hexuronic acid. On many occasions, one of the authors (IBC) had the luck and opportunity to hear from Guha all about his exciting experiences he gathered in Cambridge laboratory.

Another side of his character was also vented while staying in Cambridge. With Naziism, Fascism and war, the political climate was deteriorating in the 1930's. This had a strong influence on the faculty as well as the students of the Cambridge University. The academic community was split into pro-Soviet and anti-Soviet camps. Along with J. D. Bernal, Haldane, Needham, Waddington, Pirie and others, Guha was sympathizer of the left in its movement in England, which took a strong root through the Communist party of England. Almost throughout his active career in India, this played a predominant role, which also put him into academic trouble.

On his return to India, he was selected for the Professorship of Biochemistry at the All India Institute of Hygiene and Public Health. The appointment, however, did not materialize, because Guha's nationalist political sympathies were well known and the police report about him was unfavourable. This was an immeasurable gain to the Indian Institute for Medical Research at Calcutta, which was then being formed by a band of devoted workers wedded to the nationalist cause in scientific research. He joined it as a Founder Member and in fact wrote the public appeal for financial support. This Institute underwent transformation and metamorphosed through various stages. Eventually, the Council of Scientific and Industrial Research took it over at the instance of Jawaharlal Nehru. Today it is known as Indian Institute of Chemical Biology, and is one of the premier research institutes of Biochemistry in the country. J. C. Ray was the person who was mainly responsible for originally planning the institute. Ray and Guha were intimate friends not only socially but also scientifically. The services of Guha rendered to the institute in the early years of its struggle for existence and growth are beyond computation. His association with it continued over years and he was member of its executive council since being taken up by CSIR. The functioning of the Institute is symbolic not only of his scientific capabilities but also humanistic approaches. It is also a clear example of the coupling of scientific research to the growth of India independent from British shackles.

Since his appointment to the All India Institute of Hygiene and Public Health did not materialize, he joined Bengal Chemical and Pharmaceutical Works (BCPW) established by P. C. Ray, in Calcutta. There he founded a laboratory for nutritional research and started work immediately. Guha believed that research should be carried out to alleviate human suffering and even a single day should not be lost. Guha's dynamism and devotion to research was profound. During his short stay in BCPW (1932–35), Guha's research resulted in 38 publications, a feat unbelievable in any young researcher's life. All the publications were concerned with vitamins and nutrition. Notable among these were six publications in *Nature*[19,23,26,27,30,31], two in *Hoppe. Seyler's Z. Physiol. Chem.*[21,29] and one in *Ber. Dent. Chem. Ges.*[22]. Among the 38 papers, 7 were published in *Current Science*[16–18,20,24,25,28]. The management of Bengal Chemical became unhappy when he was fighting for better remuneration for its workers. His preceptor P. C. Ray advised him to leave Bengal Chemical and he taught Chemistry at the Vidyasagar College for a short intervening period. Eventually, he was offered the Chair of Applied Chemistry of Calcutta University in succession to H. K. Sen. Guha was in two minds about accepting the offer but he finally joined the Department in 1936 at the age of 32 as the Ghosh Professor of the University and took charge of the Applied Chemistry department. From the very beginning of his scientific career he was clear in his mind that basic research is necessary for the upliftment of the country, but applied research should be simultaneously undertaken for the benefit and proper development of the country. Thus, lifelong in his scientific approaches he had simultaneously carried out both types of research, pure and applied. While Ghosh Professor, he travelled extensively abroad and got the opportunity to visit various scientific centres in the world and was naturally influenced a lot by his exposure to the modern advancement in biochemistry. He tried to develop various divisions in the Department of Applied Chemistry like (a) Organic and Inorganic Technology, (b) Physical Chemistry and Analytical Chemistry, (c) Chemical Engineering, including elements of Electrical Engineering and (d) One elective special subject. The elective subjects were Industrial Fermentation, Oils and Fats, Ceramics as well as Pharmaceutics. Guha, as the Head of Applied Chemistry encouraged each and every section to carry out basic research as well as undertake applied research to devise new technologies, which would help the industrial enterprises to thrive. He was associated with the Applied Chemistry Department till his death except for some intervening period and the Department owes him a lot for his unusual vision for its overall growth.

Besides his own love of vitamin and nutrition, Guha guided research in fermentation studies on citric acid, acetone and butanol production, microbial jute retting and microbial spoilage of stored cereal grains. He had a quasi-permanent 'Nutrition unit' from ICMR, where he carried out an integrated programme of nutrition surveys with special reference to the vitamin and mineral contents of common Indian foods. Guha also initiated research on the nutritive value of different Indian fishes, Indian tea and hydrogenated fats. Guha noticed the widespread vitamin deficiency in Indian population, particularly vitamin A deficiency, and he compelled the Indian Government to enforce supplementation of fat-soluble vitamin A in the widely used hydrogenated vegetable oil known as vanaspati. Another scientific endeavour of Guha was in the field of designing anti-folic acid compounds and nucleic acid base analogues for their potential application in chemotherapy of cancer. In fact, a variety of these types of antimetabolites were chemi-

cally synthesized to investigate their potential use in neoplastic diseases[32–35].

In 1943, the year of the devastating Bengal famine when more than four million people died, there was a tremendous scarcity of milk and protein food. Putting all other research aside, Guha prepared vegetable milk for infants, which included malted barley and groundnut powder having almost full nutritive value of cow milk. He also prepared soybean milk at that time. He saved lives by feeding babies the artificial milk. For the adults, he started preparation of protein substitutes by isolation of proteins from grasses and leaves. He demonstrated various ways of blending such protein with human diet. This work was continued by N. W. Pirie of England, who was approached by many countries for setting up pilot plants for the production of leaf protein.

In the early forties, the special paper on industrial fermentation was replaced by Applied Biochemistry. Later, the 'Applied' was dropped and Biochemistry became a special paper in the Applied Chemistry Department. This was the forerunner of regular biochemistry M Sc Course for two years and eventually in 1956 an independent department of biochemistry was born. J. J. Ghosh was at first appointed the lecturer in the Department and later promoted to Reader and then Professor.

Being a biochemist, Guha's mind was naturally more focused on biochemistry. Initially, emphasis was laid on applied aspects of biochemistry like nutrition, food, etc. Eventually, the growth of biochemistry in the western world and emergence of Molecular Biology attracted him more and more to basic researches in biochemistry and a tendency to create a good training program of biochemistry in the country.

Guha had conflict in his mind about his twin loyalty to science and political humanism. Similarly, he was devoted to both basic science and the application of technologies in the country, as already mentioned. The latter aspect was somewhat an impediment to his proper scientific activities especially in biochemistry. Due to this, in 1944 he accepted the office of the Chief Technical Adviser to the Department of Food of the Government of India. With characteristic enthusiasm he soon organized in the Department, a Technical Wing for inspection, analysis and standardization of foods. He further initiated plans for an integrated programme on nutrition surveys for the whole country. Before Guha took up his assignment in the Food Department, there was only talk of increasing the carbohydrate content of the diets and all emphasis was laid for more output of cereals and tubers towards the objective of providing more calories. From his early experience and training in Nutrition and Biochemistry acquired while working for his doctoral degree in Jack Drummond's laboratory, Guha showed that better nutrition could be obtained even with restricted calories if the food provided were adequate with respect to proteins, minerals and vitamins. While associated with the Food Department, he conceived of plans for a Food Technological Research Institute and gave the idea a concrete shape with the active cooperation of V. Subramanyan of Bangalore who was then a Planning Officer in CSIR, New Delhi. Subsequently, CSIR established the Institute at Mysore and S. S. Bhatnagar induced Guha to serve in its Executive Council. As it will be discussed in detail later, his basic researches in biochemistry had been aligned to food and nutrition. These were mostly confined to laboratory work no doubt, but had the potentiality for applied research. His idea to get directly involved in the food production in the country was for the alleviation of poverty of his countrymen. Although he was not a technical expert he thought that he would be able to contribute significantly to the development of food technology in the country. Naturally his contributions were quite significant but the country was deprived to some extent of his expertise in the direct development of biochemistry as a discipline. Later he somewhat regretted that. This was also true when he joined the Damodar Valley Corporation (DVC) in 1948. Although this was not directly connected with his scientific experiences, he contributed to the project to such an extent that it became one of the most successful projects in this country. It is interesting to recall that DVC project was originally conceived by the internationally famous physicist M. N. Saha and nurtured to some extent by a biochemist, B. C. Guha. This changed the face of the hinterlands of Damodar river not only in preventing the early havoc created by the floods but also proper utilization of the reserved water for agricultural and other purposes including generation of electricity. The project was greatly benefited by his unusual capacity to handle applied problems. However, these activities pushed him a little further away from biochemistry, which was his primary love. He had also represented India as the first Counsellor in Agricultural Sciences, UNESCO in Paris. Besides being a member of innumerable committees, Guha was actively associated with the Board of Scientific and Industrial Research of CSIR, the Council of the National Institute of Science of India (now INSA), and the Executive Council of the Indian Science Congress Association. He was the Chairman of the Chemical Research Committee of the CSIR, Chairman of the Nutritional Advisory Committee of the ICMR, Dean of the Faculty of Science of Calcutta University. He was elected the General President of the Indian Science Congress for the year 1964. His involvement in these multiple activities was invariably linked to his motivation towards the upliftment of the country. As a committee man, Guha was sometimes vigorous, ebullient, aggressive and dominating for establishing a right cause.

In spite of the fact that he did contribute a lot towards the development of the two organizations, Food Department and the DVC, mentally he was upset as he was drifting more and more away from biochemistry, his love, and time was getting out of hand. For that reason he decided to make up that loss and joined the University back in 1953. The last phase of his life was solely devoted to the development of the Applied Chemistry department *vis-à-vis* the education and researches in biochemistry. So long biochemistry was taught as part of Applied Chemistry, but the new department of biochemistry was created in 1956 with the help of his very efficient colleagues. One of the authors (DPB) came in close contact with him during this period and was amazed to find his capabilities not only in researches but also in science administration. Guha used to confide to him that his sole object was to create a first rate department of biochemistry in the country which will have the leadership quality not only in research but also in education.

After re-joining the university in 1953 and in the years that followed, there was a rapid efflorescence of fruitful scientific activity in Guha's laboratory. During the last five years of his life, Guha and his colleagues made vital contributions in the field of ascorbic acid biosynthesis in

animals. One of the authors (I.B.C.), who joined Guha in 1953, was primarily associated with most of the publications concerned with the biosynthesis of ascorbic acid (22 publications during 1957–1962, the last five years of his life). Most of the 4000 mammalian species synthesize their own requirement of vitamin C (ascorbic acid), but only a few including humans cannot. Humans are totally dependent upon dietary source of this vitamin. Lack of vitamin C causes scurvy. Scurvy was perhaps the foremost occupational and nutritional deficiency disease that caused most suffering in recorded history. During the period of 500–1800 AD, scurvy took a toll of a few million deaths of sailors, armies and inhabitants of besieged cities. After the discovery of vitamin C by Albert Szent-Gyögryi and C. G. King (1928–1932), the knowledge of the cause and cure of scurvy was clear, but the questions remained unsolved: How is vitamin C synthesized by most animals and why are humans incapable of producing the vitamin? It took another three decades to answer these questions. The problem was solved mainly by the pioneering work of C. G. King (USA) and Guha (India) and their co-workers.

King and his co-workers showed that in the rat ascorbic acid is synthesized from glucose via the glucuronic acid pathway of metabolism: D-glucose → D-glucuronic acid → L-gulonic acid → L-gulonolactone → L-ascorbic acid. But how L-gulonic acid is converted to L-gulonolactone and L-gulonolactone to L-ascorbic acid remained riddles. Guha and his co-workers discovered and characterized two enzymes, namely, aldonolactonase (EC 3.1.1.18, L-gulonolactone hydrolase, which reversibly converts L-gulonic acid to L-gulonolactone) and L-gulonolactone oxidase (EC 1.1.3.8, L-gulonolactone: oxygen 2-oxidoreductase, which oxidizes L-gulonolactone to 2, keto-L-gulonolactone[36]. 2, Keto-L-gulonolactone is spontaneously converted to ascorbic acid. No enzyme is needed in this step. Some of the pertinent references are cited[37–47].

The significance of Guha's work on ascorbic acid biosynthesis lies in its evolutionary implications, which answered the question: Why are humans incapable of producing the vitamin? In the amphibians and reptiles, the key enzyme system mediating ascorbic acid synthesis is mainly localized in the kidneys. In most of the avian species the kidneys continue to be the main site for these enzymes until we reach the recent natural order *Passeriformis* where the liver takes over the function from the kidneys. In some species, the biosynthetic function continues to be shared between the kidneys and the liver. As evolution progressed towards the primates, the ability of the liver to mediate the key enzyme reactions was lost irreversibly, imposing on these animals a condition of dependency on the exogenous supply of the vitamin for their survival. The incapability of the guinea pig, the flying mammal (Indian fruit bat), monkey, man and the highly evolved passeriformes birds to synthesize ascorbic acid has been found to be due to a common single genetic defect, the loss of l-gulonolactone oxidase (EC 1.1.3.8), the terminal enzyme in the biosynthetic pathway. Thus, Guha's work laid the basis at the molecular level for the biochemical mechanism involved in this dependence or independence from the growth factor in different species in the evolutionary scale. This work demonstrates how a judicious use of precise methods of investigation to a fundamental problem of biosynthesis can lead to a significant result capable of a more comprehensive interpretation and general application than thought of at the beginning. This work has also shown the importance of biochemistry as the connecting link between the two extremes of molecular genetics and species evolution in life sciences. The observation became the basis of an editorial written by F. G. Young, FRS, indicating a correlation between the defect of a single gene and development of molecular pathology[48].

During this period Guha not only got involved in the development of biochemistry in his own university but also the whole country. From 1953 onward, till the last day of his life, Guha had two distinct visions and the urge to execute them: (i) to find ways and means for materializing the scientific policy resolution approved by the Government of India on 12 March 1958 with Jawaharlal Nehru as the Prime Minister and (2) to develop teachings and research in modern biochemistry throughout the country. Regarding the first one, Guha emphasized[49] that 'Unless the Government is bold enough in adopting reforms, which will enable scientists and technologists to pull their weight in the rapid economic development of the country, the scientific policy resolution will remain a resolution and will not sufficiently sub serve the interests of the nation'. He further pointed out that 'In implementing the resolution, Government would have to pay attention to science teaching in schools, colleges and universities. Schools are, by and large, ill-equipped and ill-staffed for science teaching. It is there that the foundation should be laid. If proper salary scales are not provided for school teachers and money is lacking for experiments and demonstrations, it is idle to expect a radical improvement in the situation regarding scientific personnel. Besides, it is at the school stage that special efforts should be made to spot the most creative minds and give them special opportunities for development by way of high-class merit scholarships, special arrangements for teaching and accommodation, etc. What applied to schools, applies also to colleges and universities. Here also the career of a teacher should be made sufficiently attractive, both materially and psychologically, and special opportunities should be given for the development of the most original and vigorous minds among the students. The science departments of the colleges and universities should have annual adequate bloc grants, so that the teachers engaged in research may concentrate on their work without worrying about research expenses and without begging for funds from sundry organizations. Nothing is more depressing than this constant anxiety for funds for research'[49]. It is unfortunate that fifty years have passed by since Guha suggested the remedial measures, but apparently very little has been done. A shabby condition still persists in most teaching institutions in our country. Although the Government has adopted some reform by which the scientists in different national laboratories are being able to do good research, the universities, colleges and particularly the schools are still, by and large, ill-equipped and ill-staffed for science teaching. Sincere remedial measures are yet to be taken to overcome the situation. A recent picture of distress of the university education is apparent from Balaram's view: 'University science departments, and I believe there must be very few exceptions, have become academically fossilized'[50].

Regarding development of teaching and research in biochemistry, Guha realized in mid-fifties that biochemistry was gradually becoming the lifeblood of fundamental studies in all the biological sciences. In 1956, at a meeting of the

Society of Biological Chemists (India) held in Calcutta[51] he said, 'It may not be hazardous to predict that in the next ten or twenty years, perhaps the most revolutionary developments will be witnessed in the domains of (a) nuclear physics and chemistry and (b) biochemistry and biophysics'. Guha emphasized on interdisciplinary research even at that early stage. He said 'In biochemistry the more there is integration between different lines of researches, the more rapid becomes the advance in these different lines and the clearer become the interrelationships which underlie all vital phenomena. There is a great need for joint seminars and discussions even in apparently unconnected fields of biochemistry because these are likely, by and large, to throw fresh light on perplexing problems. There can be no doubt that in future years, the pursuit of biochemistry will prove more and more an exciting adventure and, may I say, almost a romance'[51]. Guha realized that for rapid economic development of the country, applied research should also be pursued with great momentum along with the fundamental research. In mid-fifties, most biochemical preparations of commerce were imported. He emphasized, 'Here is a great field which should be ploughed by scientists even in universities and other research institutions, as private industry is rather shy in this country and does not like to take risks. Similarly, instrumentation should receive special attention in India. It is undesirable that practically all fine instruments of measurements should have to be imported. Biochemical researches in these days are greatly dependent on such instruments and biochemists in this country should make a special plea for the manufacture of these instruments'[51].

From 1959 onwards, biochemical education and research in India took a great leap. The contribution made by a few young biochemists with Guha as the leader will ever be remembered by all biochemists of our country. In fact, apart from his versatile activities and extraordinary range of remarkable accomplishments, this leadership made Guha immortal among all the practitioners of biological science in this country. In 1959, at his insistence, D. S. Kothari, Chairman of the University Grants Commission, appointed a committee under Guha's chairmanship to assess the status of biochemistry in the country and suggest means and methods for improvement of biochemical education. That was a wise decision made at that time and whatever biochemistry is today in the country is due to these decisions. Notable among the members were Hussain Zaheer, Director, Regional Research Laboratory, Hyderabad, P. S. Sarma, Head of the department of Biochemistry, Indian Institute of Science, Bangalore, P. S. Krishnan, Head of the Department of Biochemistry, University of Lucknow, B. Mukerji, Director, Central Drug Resaerch Laboratory, Lucknow and V. Jagannathan, Assistant Director, Biochemistry Division, National Chemical Laboratory, Poona. The analysis of the achievement of Biochemistry made up to that time and the recommendations made for teaching and research in Biochemistry were most valuable. These recommendations led to the creation of a large number of Departments of Biochemistry in various Universities and Centres in different Institutions. Initially Guha played a pivotal role in this development. The Biochemistry Review Committee held three meetings, the first in January 1959 at Delhi, the second in April 1960 at Lucknow, and the third in March 1961 at Bangalore. Guha approved the first draft of the report, but most unfortunately he suddenly died in March 1962 before it could be finalized. In this report the then position of biochemical studies and research in India has been analysed and certain lines about their future development are indicated. It has been recommended that in the universities where biochemistry is taught at present and in a few more centres where it is going to be taken up, independent Departments of Biochemistry should be organized on the basis of adequate staff to impart proper education to the students. Guha occupied a leading place in the scientific community of our country and by his untimely death Indian science has suffered a serious loss. After his sad demise at a comparatively early age, P. S. Sarma of the Department of Biochemistry, Indian Institute of Science, Bangalore, took great pains to continue his unfinished work. We are also indebted to the teachers of Biochemistry Departments in Universities for their keen interest and co-operation in the work of the Committee. The Committee had the benefit of help and advice of Robert H. Burris, Professor of Biochemistry at the University of Wisconsin, USA, who visited India under the Wheat Loan Educational Exchange Programme. The document prepared by this Committee is of immense value not only as a historical record but a guidebook for future development of biochemistry in the whole country. Perhaps this is one of the outstanding contributions of Guha for which he literally became the father of modern biochemistry in India.

One of the other memorable works, which Guha initiated, but was not able to implement fully was the organization of a Summer School at Srinagar during May–June 1962. That may be deemed as the dawn of Modern Biochemistry in India. The reason is very simple. A group of young biochemists, most of them from various disciplines and trained abroad in biochemistry assembled on that occasion to deliver lectures in the subject areas which were in the developing stage in the West. That the impact of biochemistry was already felt in the country was obvious from two steps taken: one by the formation of a Biochemistry Review Committee with Guha as the Chairman, as stated above, and the other by the Ministry of Scientific Research and Cultural Affairs under the inspiring guidance of Humayun Kabir, the then Minister at the Centre. The step taken by Humayun Kabir was to initiate Summer Schools in the areas, which had the potential to grow, biochemistry being one of them. In fact, Guha was also supposed to organize the summer school but unfortunately he died before he could undertake the job. So P. S. Sarma, who comparatively recently joined the Department of Biochemistry of the Indian Institute of Science, had to carry out the job in place of Guha. He acted as the first director of the summer school. Sarma was an appropriate person to complete the job left unfinished by Guha because like Guha he was also deeply interested in the development of Biochemistry all over India. In a sense, he completed some of the unfinished jobs, which Guha dreamt of. Quite a few new centres were brought into existence due to serious attempts made by him. Other than that he tried his best to choose the most capable persons to organize the departments. We presume that the biochemists in India in general feel indebted to him for whatever little has been achieved in biochemistry in the country. The proceedings of the summer school were published as *Advances in Biochemistry* in 1963 by the Indian Institute of Science, Bangalore with P. S. Sarma as the Editor.

This was the first record of the advances made in the country and abroad in biochemistry, eventually leading to the emergence of Molecular Biology in the proper sense in this country.

Shortly before this period one of the authors (DPB) had the unique opportunity of coming in close contact with Guha while the latter visited New York in connection with a symposium held on 'ascorbic acid' on 7 and 8 October 1960, where most of the stalwarts involved in unravelling mechanism of ascorbic acid synthesis participated. Since he spent more than a week with the author as his guest, the latter could get glimpses of his inner mind. The discussions that continued till late night were mostly concerned with the development of biochemistry in the country. He had no hesitation to admit that biochemistry had suffered a lot in the country due to his adventures or rather misadventures in the areas not directly linked to biochemistry. He elaborated his plans on how he wanted to make up the loss by developing the separate department of biochemistry in the University College of Science, Calcutta, which would provide the leadership not only in research but also in education. It is agreed that Indian Institute of Science is no doubt the oldest organization of the country and the excellent research work carried out there provides guidance to many, but unfortunately, they are not interested in teaching biochemistry at the postgraduate level. Although he never expressed what was in his inner mind, one of the authors (DPB) had a jolt from the blue shortly after his return to the country. On Guha's insistence and practically marching orders he had to join the newly created department of biochemistry in 1962. Prof. Guha was so good a planner that he had already talked to the Director of Bose Institute, where the former (DPB) spent almost 15 years to carry out his researches and built an excellent biochemistry laboratory with all facilities for researches on enzymes and nucleic acids. He made a unique approach, which is somewhat unusual in the country that DPB would teach in the department of biochemistry, University College of Science Calcutta next door, but continue his research activities in Bose Institute as usual. There was no other alternative than to succumb to his special request but eventually for the same reason he had to quit both the organizations. In early 1962 when his plan to create an Advance Centre of UGC in the department of biochemistry of the University of Calcutta was almost complete, Guha suddenly died and that was practically the end of his last adventure for the development of biochemistry.

A biography of Guha will remain incomplete if a few words are not mentioned about Phulrenu Guha, the illustrious wife of Guha. They were married on 17 July 1945 at Calcutta. This marriage proved to be a turning point in Guha's work and career in more than one ways. But for the wise counsel and devoted guidance of his wife, Guha, with his indomitable spirit, aggressive mentality and burning desire for breaking the shackles and obtaining freedom for his country, would have landed himself behind the prison bars and would have been lost forever to the world of science. The genial influence of his wife channelized his creative energies into a fruitful academic and laboratory life and into various social and cultural activities. Mrs Guha took her M A degree from Calcutta University and doctorate degree in Social Science from Sorbonne University of Paris. Both had known each other for a long time in connection with their activities as freedom fighters. Subsequently, Mrs. Guha became the Minister of Social Welfare, Govt. of India. For a long time, she was an MP, member of the Rajya Sabha, and President and Chairperson of innumerable number of committees, including Central Social Welfare Board, Indian Council of Child Welfare, Indian Council for Mass Education and Development, Status of Women of India, Centre for Women's Development Studies and many others. She was awarded Padma Bhushan in 1977. In spite of their extremely busy individual schedules, both Prof. and Mrs Guha were a source of inspiration to each other. All their thoughts and deeds were for the betterment and upliftment of the whole of India: Guha for science and technology and Mrs Guha for the society, particularly for the children, destitute and the backward class. Little did they care for their own personal benefit. One of the authors (IBC) heard from Mrs Guha that because they were extremely busy with their preoccupations, they did not have any children. They did not regret it as Guha's students were considered their own. At the age of 95, Mrs Guha lives a very simple life, staying in a rented house, still very busy with social welfare. She sold all her properties, including the residential building and donated the money to Calcutta University for creating a Chair in the B. C. Guha Centre for Genetic Engineering and Biotechnology. To pay tribute and honour to the outstanding teacher, Calcutta University has established the B. C. Guha Centre.

Guha is remembered by all scientific workers of the country carrying out research on biological sciences with deep affection and respect. The depth of respect is realized by the name of a unique conference in India, the GRC. GRC plays a very important role in the development of biological sciences, including biochemistry, biophysics, cell biology, microbiology, etc. GRC is a three-letter abbreviation of Guha Research Conference. The initial nickname of the conference was 'Khandala type conference', because the first conference was held in Khandala of Maharashtra. The real credit of initiation of such a conference goes to Pushpa Bhargava. About a dozen brains of some young Indian biochemists, most of whom returned from abroad after receiving advanced training were inseminated by Pushpa for an informal get-together. The first four meetings were held at the time of sessions of the Indian Science Congress. The day after the gala opening of the Congress by the Prime Minister, a handful of the biochemists used to move out of the main city and gather in a small place nearby to critically discuss their individual research findings till late hours with utmost devotion. Later, in an informal meeting of the group at Bangalore, it was felt that the conference should be held independently of Science Congress and it should be registered as a society for financial support. But most of the members were dead against forming a society with regular office bearers. Finally a compromised formula was drawn that it would be formed as a society with only a convener for management purpose to organize the meeting every year. In a sense, this conference is unique in the world. Next, another problem arose about the naming of the conference. Although previously the name Khandala type of meeting was used, that was not really the description of the meeting. One of the authors (DPB) proposed that the conference be named as Guha Research Conference (GRC). Every one of the members present unhesitatingly accepted the proposal, because all the young biochemists highly respected Guha. On the one hand, Guha

had become a kind of institution in the scientific pursuit of the country, and on the other hand he helped a vast body of students and scientific workers by providing research grants, advice and guidance for doing research of the international standard. This name of GRC itself reflects deep affection and respect for the outstanding Indian biochemist.

Guha's death was a bolt from the blue. At the invitation of B. Mukerji, the then Director of CDRI, Dr and Mrs Guha, on their way back from Delhi, halted at Lucknow for a completely relaxed holiday. After spending the day and the evening with great delight and innate sense of humour, Guha suddenly felt uneasy and fell down on the floor and expired within minutes. That was 20 March 1962. The spirited champion of life was also a champion in death. The next morning his mortal body was flown to Calcutta and was kept in the cold room of the Department of Applied Chemistry, where innumerable students, associates, admirers and relatives of Guha were present to pay their homage. Incidentally, Guha built the cold room for carrying out research on biochemistry.

Guha was a man of great personal charm and infectious enthusiasm. His command over Sanskrit and Bengali literature was remarkable. So was his assimilation of English literature. He could recite Kalidasa, Shakespeare and Rabindranath with equal fluency and effect.

In the shifting sands of time, men will come and men will go. Only very few can leave behind a bold mark of unusual leadership which remains indelible. Guha undoubtedly succeeded in leaving such a memory trace in the fluorescent screen of many minds.

Source materials

1. *The Days I Left Behind: An Autobiography of a Teacher, a Scientist and a Physician* by Sachchidananda Banerjee. 'Prof. S. Banerjee Felicitation Committee', Department of Physiology, Presidency College, 86/1 College Street, Calcutta 700 073, First published in November 1999.
2. *In memoriam* by J. C. Ray in *Annals of Biochemistry and Experimental Medicine*, 1962, **22**, 125–128.
3. *Prof. B. C. Guha* by I. B. Chatterjee, 1998, Jnan-O-Bijnan, 8th issue, pp. 289–291 and 11th issue, pp. 493–495.
4. Souvenir published on the occasion of Golden Jubilee Celebration and thirty-fifth reunion of Applied Chemistry, University of Calcutta, 21 February 1976.
5. *Dr B. C. Guha, the Man and his Work*, by B. Mukerji, Memorial Lecture delivered on 20 March 1964, at Calcutta.
6. Souvenir published on the occasion of Prof. B. C. Guha Birth Centenary Celebration, Department of Biochemistry, University of Calcutta, 7 and 8 June 2004.

1. Funk, C. J., *J. Physiol.*, 1912, **45**, 489.
2. Funk, C. J., *J. Physiol*., 1913, **46**, 173.
3. Jansen, B. C. P. and Donath, W. F., *Proc. Acad. Sci. Amsterdam*, 1926, **29**, 1390.
4. Guha, B. C. and Drummond, C. J., *Biochem. J*., 1929, **23**, 880.
5. Guha, B. C., *Br. Med. J*., 1931, **2**, 53.
6. Guha, B. C., *Biochem. J*., 1931, **25**, 931.
7. Guha, B. C., *Biochem. J*., 1931, **25**, 945.
8. Guha, B. C., *Biochem. J*., 1931, **25**, 960.
9. Guha, B. C., *Biochem. J*., 1931, **25**, 1385.
10. Birch, T. W. and Guha, B. C., *Biochem. J*., 1931, **25**, 1391.
11. Guha, B. C. and Mapson, L. W., *Biochem. J*., 1931, **25**, 1974.
12. Guha, B. C., *Lancet*, 1931, **1**, 864.
13. Guha, B. C., *Nature*, 1931, **127**, 594.
14. Szent-Györgyi, A., *Biochem. J*., 1928, **22**, 1387.
15. Szent-Györgyi, A., *Annu. Rev. Biochem., J*., 1963, **32**, 1.
16. Guha, B. C. and Biswas, H. G., *Curr. Sci.*, 1934, **2**, 474.
17. Guha, B. C. and Ghosh, A. R. *Curr. Sci.*, 1934, **3**, 201.
18. Guha, B. C. and Das, N., *Curr. Sci.*, 1934, **3**, 157.
19. Guha, B. C. and Ghosh, A. R., *Nature*, 1934, **134**, 739.
20. Guha, B. C. and Ghosh, A. R., *Curr. Sci.*, 1934, **2**, 390.
21. Das, N. and Guha, B. C., *Hoppe. Seyler's Z. Physiol. Chem*., 1935, **231**, 157.
22. Guha, B. C. and Biswas, H. G., *Ber. Dent. Chem. Ges.*, 1935, **68**, 427.
23. Guha, B. C. and Ghosh, A. R., *Nature*, 1935, **135**, 234.
24. Guha, B. C. and Biswas, H. G., *Curr. Sci.*, 1935, **3**, 300.
25. Guha, B. C., *Curr. Sci.*, 1935, **3**, 565.
26. Guha, B. C., *Nature*, 1935, **135**, 395.
27. Guha, B. C. and Ghosh, A. R., *Nature*, 1935, **135**, 871.
28. Ghosh, B. N. and Guha, B. C., *Curr. Sci.*, 1935, **3**, 554.
29. Das, N., Ghosh, B. N. and Guha, B. C., *Hoppe. Seyler's Z. Physiol. Chem.*, 1936, **238**, 131.
30. Guha, B. C. and Pal, J. C., *Nature*, 1936, **137**, 946.
31. Guha, B. C. and Pal, J. C., *Nature*, 1936, **137**, 946.
32. Ghosh, S., Roy, D. and Guha, B. C. *Nature*, 1958, **182**, 187.
33. Ghosh, S., Roy, D. and Guha, B. C., *Naturwissenschaften*, 1958, **5**, 115.
34. Roy, D., Ghosh, S. and Guha, B. C., *Naturwissenschaften*, 1958, **16**, 392.
35. Roy, D., Ghosh, S. and Guha, B. C., *J. Org. Chem.*, 1960, **25**, 1909.
36. Enzyme nomenclature, IUPAC AND IUB, 1972, pp. 64–65 and 194–195.
37. Chatterjee, I. B., Ghosh, N. C., Ghosh, J. J. and Guha, B. C., *Science*, 1957, **126**, 608.
38. Chatterjee, I. B., Ghosh, N. C., Ghosh, J. J. and Guha, B. C., *Biochem. J*., 1958, **70**, 509.
39. Roy, R. N. and Guha, B. C., *Nature*, 1958, **182**, 319.
40. Roy, R. N. and Guha, B. C., *Nature*, 1958, **182**, 1689.
41. Chatterjee, I. B., Chatterjee, G. C., Ghosh, N. C., Ghosh, J. J. and Guha, B. C., *Naturewissenschaften*, 1959, **46**, 475.
42. Chatterjee, I. B., Ghosh, N. C., Ghosh J. J. and Guha, B. C., *Naturwissenschaften*, 1959, **46**, 580.
43. Chatterjee, I. B., Chatterjee, G. C., Ghosh, N. C., Ghosh, J. J. and Guha, B. C., *Biochem. J*., 1960, **74**, 193.
44. Chatterjee, I. B., Chatterjee, G. C., Ghosh, N. C., Ghosh, J. J. and Guha, B. C., *Biochem. J*., 1960, **76**, 279.
45. Chatterjee, I. B., Kar, N. C., Ghosh, N. C. and Guha, B. C., *Arch. Biochem. Biophys*., 1960, **86**, 154.
46. Chatterjee, I. B., Kar, N. C., Ghosh, N. C. and Guha, B. C., *Nature*, 1961, **192**, 163.
47. Kar, N. C., Chatterjee, I. B., Ghosh, N. C. and Guha, B. C., *Biochem. J*., 1962, **84**, 16.
48. Young, F. G., *Br. Med. J*., 1960, **1**, 1960.
49. Guha, B. C., *Scientific Policy of India, Science and Culture*, 1958, **23**, 567.
50. Balaram, P, Training a new generation, Editorial, *Curr. Sci.*, 2004, **86**, 1583.
51. Guha, B. C., Progress of Biochemistry in India, Lecture in *Soc. Biol. Chem. India*, Calcutta, 1956.

ACKNOWLEDGEMENTS. The article is based on the long association of one of the authors (IBC) with Prof. B. C. Guha and the materials collected by the other (DPB) as Editorial Fellow for recording the history of Biochemistry of India under the Project on the 'History of Science, Philosophy and Culture' of which Prof. D. P. Chattopadhyay is the Chairman.

I. B. Chatterjee is at the Dr B. C. Guha Centre for Genetic Engineering and Biotechnology, University College of Science, Kolkata 700 019, India and D. P. Burma is at PHISPS, CF 186, Salt Lake, Kolkata 700 064, India*
**For correspondence.*
e-mail: dpburma@hotmail.com