KRAMADHATI VENKATA GIRI

(1907-1958)

Elected F.N.I. 1956

Birth, Parentage and Childhood

Kramadhati Venkata Giri was born in the year 1907 in a remote village near Madanapalle in Andhra Pradesh where his father, Shri K. Surappa lived. Giri at a very young age ventured out of his village to Madanapalle for his early education.

Formative Influence on the Young Scientist

As a young student in the Madras University, Giri set for himself high standards of morality and dedication in achieving his goals, preparing himself to obtain the best possible education to enable him finally to become one of the leading biochemists of his time.

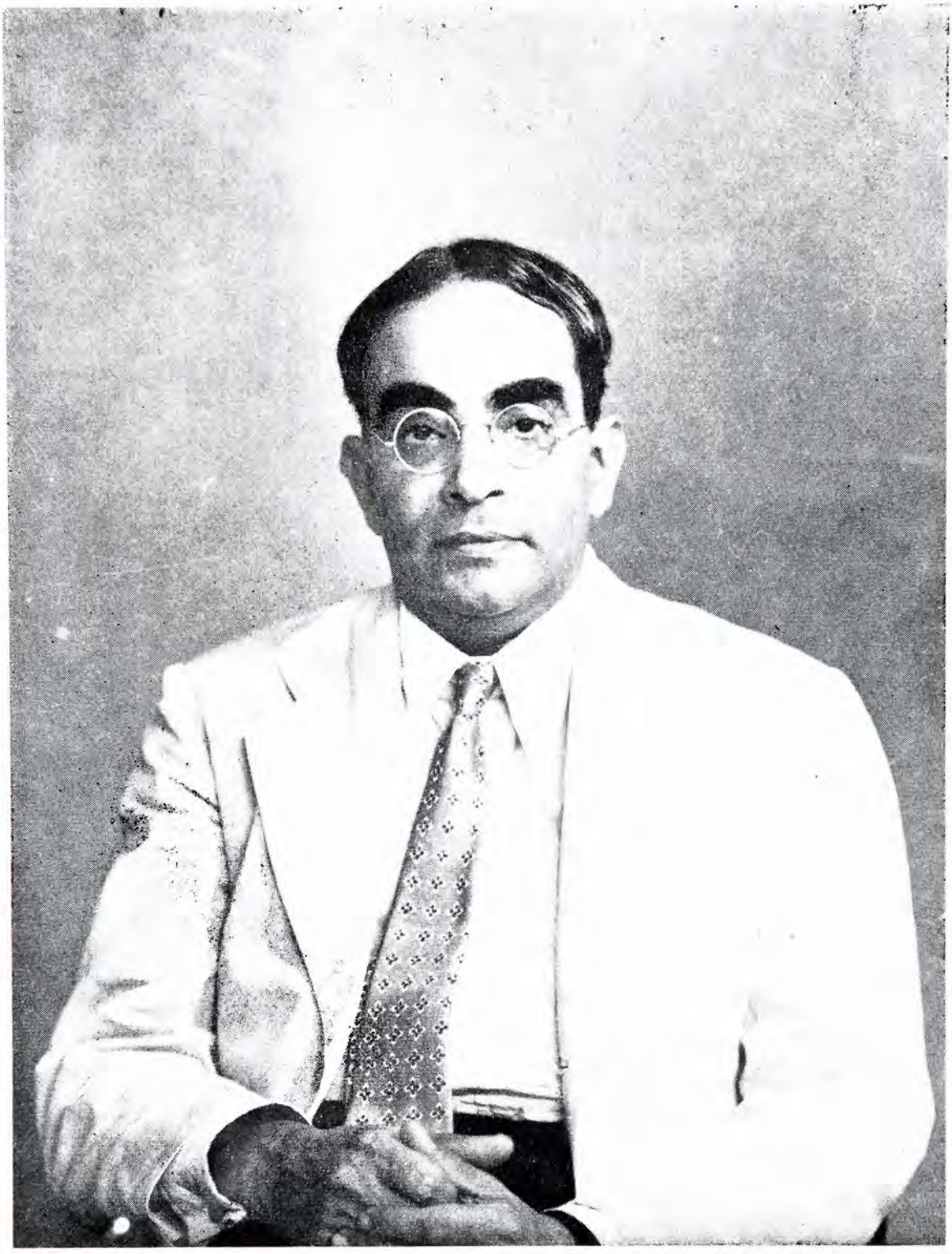
School and University Education and Research

Giri obtained the B.A. degree of the Madras University from the St. Joseph's College, Tiruchirappally. He took the M. Sc. degree of the University of Calcutta and then joined the Department of Biochemistry, Indian Institute of Science, Bangalore in 1929. His early work on 'Investigations on Enzymes' gained for him the degree of Doctor of Science of the Calcutta University in 1938.

Professional

After two years of service as Enzyme Chemist at the Nutritional Research Laboratories, Coonoor (1939-40) and three years as Gowthami lecturer and later Reader in Biochemistry at the Andhra University, Dr. K. V. Giri returned to the Institute at Bangalore to become a lecturer in Biochemistry in 1943. He was elevated in 1950 to the Professorial Chair in Biochemistry, a post he held till the end. During 1949-50, Prof. Giri was associated with Prof. H. von Euler at the University of Stockholm, Sweden and visited Norway, Denmark and England. He presided over a session of the International Symposium on *'Enzyme Chemistry'* held in Tokyo in the autumn of 1957. Prof. Giri was actively associated with executive and advisory committees of several universities, research institutions and technical bodies, both in India and abroad.

Till the very end, Prof. Giri was greatly devoted to science and in the spread of biochemical knowledge for exploitation of abundant vegetable and animal



V. V. Giri

resources. He held the firm conviction that to achieve this end, economical and highly simplified biochemical techniques are necessary pre-requisites. He spared no pains to popularise these techniques through his writings, lectures, radio-talks visual demonstrations by charts and cine films. He took great delight in assiduously collecting photographs and life sketches of famous scientists, particularly, Nobel Laureates. His chief pleasure was in the laboratory where he preferred to work himself rather than to entrust to others. Until his passing away, he had great admiration for his colleagues and students all of whom he treated with extreme affection in the laboratory and his home

The sudden demise of Prof. Giri on 17 July 1958 in Madras took away from our midst a well-loved personality and a distinguished biochemist of our country.

Contributions to New Knowledge

Water-soluble vitamins

Thiamine (Vitamin B_1): A simple and rapid method for the estimation of vitamin B_1 in foodstuffs was developed and the amounts of this vitamin in groundnut, during germination and under different conditions of manuring, were estimated. Investigations were also carried out on its biosynthesis in molds and by the intestinal flora of rats under different dietary supplements like milk, curds, fats or on the administration of sulphaguanidine, *p*-aminobenzoate and penicillin.

Biotin: It was shown that administration of excess amounts of biotin to rats leads to an increased synthesis and accumulation of cholesterol in tissues and that these effects could be reversed by giving inositol.

Ascorbic Acid: Giri's studies on the analytical chemistry of ascorbic acid and on its stability under varying environmental conditions, are also worthy of mention. The mechanism of the inhibitory action of ascorbic acid on important enzymes like amylases and phosphatases was also investigated.

Riboflavin (Vitamin B_2): Of considerable interest is his observation that a mutant of yeast, *Saccharomyces cerevisiae,* excreted considerable amounts of this vitamin into the medium. This work on riboflavin eventually led to extensive investigations on the flavin coenzymes.

Enzymes

Professor Giri was a pioneer in enzyme research and his earliest studies were concerned with purification and documentation of the properties of some key enzymes in intermediary metabolism, viz., phosphatases, amylases, lipases and proteases. Much of this work was published in *Zeitschrift fur Physiologische Chemie, Biochemiche Zeitschrift, Biochemical Journal, Nature and Enzymologia.*

Carbohydrate Metabolism

A systematic search for phosphorylase in Indian pulses showed that green gram was a good source of the enzyme. The enzyme was purified and its nature and behaviour towards various substances of biological importance were studied. A method was developed for the preparation of glucose-1-phosphate, using green

gram extract as a source of phosphorylase. In addition to phosphorylase, another enzyme with the branching factor or Q enzyme which takes part in the synthesis of starch was isolated from green gram and its characteristics were studied.

Evidence in support of the existence of Embden Meyerhof glycolytic pathway in green gram was advanced through indentification and isolation of all the enzyme systems involved. Phosphorylated glyceric acids were shown to be very effective precursors for sucrose synthesis in green gram.

An enzyme capable of building up glucofructosans from sucrose was detected in water extracts of the tubers of *Crinum longifolium* and *Crinum latifolium*. It was concentrated and purified from associated carbohydrates and its characteristics were determined. Normally, sucrose acts as the acceptor as well as the donor of fructosyl residues. Raffinose also was found to act as a substrate; it builds up two oligosaccharides when acted upon by this enzyme. It was shown that neither glucose nor fructose acts as an inhibitor.

The penicillin producing strain *P-chrysogenum* Q 176 was capable of synthesizing various types of oligosaccharides when grown in a medium containing maltose and sucrose. Enzymes capable of synthesizing these oligosaccharides were prepared in pure form by passing through starch column and by subsequent alcohol precipitation. All the oligosaccharides synthesized from maltose were identified and characterized by means of periodate oxidation, physical constants, mobility on paper chromatograms and by comparison with acid hydrolysates of known polysaccharides.

Nitrogen Metabolism

A systematic survey of the free amino acid content of several edible leaves and leaves of the citrus family was made. Citrus leaves contain a good percentage of proline. A high concentration of asparagine was observed in betel leaves. Hydroxyproline was found to occur in the leaves of sandal in high concentrations; the flowers and pericarp contained the highest percentage. This amino acid was isolated by a combination of ion-exchange and circular paper chromatography and was characterized by physical and chemical methods as allo-hydroxy-L-proline. This is the first report of free hydroxyproline in the plant kingdom.

Cell-free extracts of green gram were found to synthesize glycine from a variety of amino acids by transamination with glyoxylic acid.

Partial purification of the enzyme, arginase, from field beans (*Dolichos lablab*) was effected and the kinetics of metal ion activation was studied. The enzyme activity was unaffected by copper and cadmium, but was inhibited by borate, citrate, cystine, ornithine and lysine. The presence of transaminases, viz., glutamic acid-alanine and glutamic acid-aspartic acid, in some of the Indian pulses was detected by paper chromatography. The glutamic-aspartic transaminase was inhibited by pterygospermin, an antibiotic isolated from the roots of the drumstick tree (*Moringa pterygosperma*).

An enzyme which converts riboflavin to flavin mononucleotide (FMN) was purified from green gram extracts, with a recovery of about 40%. The conversion of riboflavin to FMN was nearly 60%.

An enzyme which hydrolyses flavin adenine dinucleotide (FAD) to FMN and adenosine-5'-phosphate (AMP), was obtained in crystalline state from green gram seedlings. Its optical *p*H was 9.0–9.4. At the ammonium sulphate stage of purification and on treatment with glutathione (GSH), this enzyme gave riboflavin, pyrophosphate and adenosine. This alteration of the site of attack is inhibited by phosphate ions. Further, the inhibition of the original activity (i.e., FAD to FMN and AMP) together with a change in the spectrum of the enzyme, on the addition of phosphate indicates the key role played by phosphate ions in this activity.

The FAD hydrolase was purified 300-fold from germinating seedlings of green gram. It was inhibited by EDTA and the inhibition could be reversed only by Zn^{2+} and Co^{2+} ions. Zinc ions at concentrations above 1×10^{-4} M inhibited the EDTA-treated as well as the untreated enzymes. This effect of Zn^{2+} ions is similar to that observed in the case of well-known regulatory enzymes which are inhibited either by excess substrate or co-factor. Similarly, this enzyme was inhibited by pyrophosphate, ATP and AMP, EDTA and activation of the EDTA-inhibited enzyme by Zn^{2+} followed a typical allosteric pattern.

AMP is an allosteric inhibitor for the crystalline FAD-hydrolase from mung bean (*Phaseolus radiatus*). One of the sites of AMP inhibition could be desensitized by P-chloromercuri-benzoate (PCMB) or N-ethyl maleimide or by ageing. A partially inactivated enzyme could be reactivated by low concentrations of adenosine diphosphate (ADP).

Riboflavin Metabolism in Plants

It is well known that the B-vitamins occur abundantly in higher plants. With the demonstration that some of the B-vitamins like nicotinic acid and riboflavin function as components of enzymes, increasing attention was devoted to the study of the role of these vitamins in plants. Investigations were carried out on the forms in which riboflavin occurs in plants and on the enzymatic synthesis of the flavin coenzyme nucleotides.

Starting with riboflavin, FMN is synthesized by the enzyme flavokinase by an irreversible reaction with ATP. The partially purified (75-fold) enzyme functions optimally at a temperature of 55 °C and *p*H 8.6. The high temperature optimum, although very unusual for enzymes in general, is not uncommon in plants. The substrates (riboflavin and ATP) exert a protective action against heat denaturation and this would, to a certain extent, explain the activity at high temperature. It is highly specific for the flavin, but not so specific for the phosphate donor.

FAD is synthesized from FMN and ATP and this reaction is catalysed by the enzyme, FAD synthetase, which functions optimally at a temperature of 37 °C and *p*H 7.5. The 83-fold purified enzyme is specific for its substrates FMN and ATP, and it showed some hydrolytic activity which was very much less than that of the crude extract; this suggested the possibility that in addition to the hydrolysis by the reversal of FAD-synthetase, FAD may also be hydrolysed by a specific enzyme.

Studies on Blood Coagulation

Prof. Giri was one of the leading research workers of his time who initiated a systematic study of the mechanism of blood coagulation. His painstaking work on the separation of various protein factors involved in blood coagulation, the study of their interactions and the isolation of anti-coagulant factors from indigenous plant sources, represented his major work in this area.

Paper Chromatography

Prof. Giri and his associates made important contributions to the development of paper chromatography as a powerful tool in biochemical research. Particular mention may be made of the development of a paper chromatographic technique for the separation and identification of enzymes, for the qualitative and quantitative analysis of a variety of biochemically important compounds like amino acids, sugars, organic acids, etc.

It was shown that enzymes could be made to move on paper employing aqueous acetone or alcohol or salt solutions as the developing solvents. The position of the enzymes on the developed chromatograms was located by the agar plate method.

The circular paper chromatographic technique developed by him has proved to be a simple, elegant and rapid method for the separation and identification of many biological metabolites. The wide application of this method in diverse fields is indicative of its advantages, in certain respects, over the conventional methods.

Agar Electrophoresis

Prof. Giri and his colleagues also developed a simple technique of agar electrophoresis for the separation of serum proteins. In this modification of the well-known paper electrophoresis method, the filter paper is replaced by agar gel layered between glass plates, as the medium. The method is simple, quick and efficient in the resolution of protein components without adsorption. Further, this technique affords the separation in the serum of a larger number of components than those obtained by paper electrophoresis.

A simple method of two-dimensional agar electrophoresis was developed by which mucoproteins could be separated into well-defined zones. The mucoprotein spots could be identified by fuchsin sulphate spray after periodate oxidation. This technique is useful for the examination of the changes in mucoproteins in pathological samples of blood and urine.

Prof. Giri felt the need to spread biochemical knowledge widely and made a hobby of devising scientific films. He wanted every medical practitioner in India to have access to clinical biochemical services and this objective was stressed through his films, writings, radio talks and lectures.

Marriage, Wife and Private Life

Prof. Giri married the daughter of Shri H. Krishna Sastri, the first Indian Chief Epigraphist to the Government of India. His wife, Smt. Janakamma took a deep

interest in his work and helped to translate many of his publications into Telugu and Kannada.

Prof. Giri has four children, two sons and two daughters. His eldest son, Dr. K. V. Ravi, has specialised in material science and is now working as the Technical Director of MOBILE-TYCO laboratories in U.S.A. and is directing research programmes in the area of solar energy. His second son Shri K. V. Chandrasekhar, is Managing Director of M/S. Sekhar Electronic Industries Pvt. Ltd., a company engaged in the manufacture of electronic components in Bangalore.

His first daughter, Smt. Usha is a qualified Chartered Accountant and his second daughter, K. V. Amba is a Computer Scientist.

N. APPAJI RAO
C. S. VAIDYANATHAN
H. R. CAMA

BIBLIOGRAPHY

1931. (WITH MIRCHANDANI, T. J., *and* SUBRAHMANYAN, V.). Studies in electro-culture. Part I. Introduction. *J. Indian Inst. Sci.*, **14,** A, 67.
— (WITH SUBRAHMANYAN, V.). Studies in electro-culture. Part II. Influence of electrical treatment on the germination and the diastatic activity of malt. *J. Indian Inst. Sci.*, **14,** A, 78.
1932. Ageing of amylases in aqueous solution. *J. Indian Inst. Sci.*, **15,** A, 107.
— Heat inactivation of pancreatic amylase. *J. Indian Inst. Sci.*, **15,** A, 117.
1933. A new method for the separation of the two components of amylase. *Curr. Sci.*, **2,** 128.
— (WITH GHATAK, N.). Peroxidase from the fruits of *Tribulus terrestris* Linn. *Bull. Acad. Sci., U.P.*, **2,** 171.
1934. On the characterisation of different amylases. *J. Indian Inst. Sci.*, **17,** A, 127.
— Amylase from sweet potato (*Ipomoea batatas*). *J. Indian chem. Soc.*, **11,** 339.
— Die chemische natur der amylase-die amylase des batate. *Biochem. Z.*, **275,** 106.
— The chemical nature of enzymes. *Curr. Sci.*, **3,** 276.
1935. (WITH SHRIKHANDE, J. G.). Studies in salt activation, Part I. Influence of neutral salts on the enzyme hydrolysis of starch. *J. Indian chem. Soc.*, **12,** 273.
— Studies in salt activation. Part II. Influence of salts on the stability of amylase. *J. Indian chem. Soc.*, **12,** 567.
— A new method of differentiation of amylases and starches. *Sci. N. Y.*, **81,** 343.
1936. (WITH DATTA, N. C.). Phosphatases of the brain. *Curr. Sci.*, **4,** 833.
— (WITH SREENIVASAN, A.). The amylase system of rice grain during ripening and germination. *Nature,* London, **138,** 406.
— (WITH DATTA, N. C.). Brain phosphatase. *Biochem. J.*, Cambridge, **30,** 1089.
— Uber fruenmilch-phosphatase. *Z. fur physiol. Chem.*, **243,** 57.
— Pyrophosphatase of soya bean (*Glycine hispida*). *Curr. Sci.*, **4,** 833.
— Uber Speichel-phosphatase. *Biochem. Z.*, **285,** 306.
— Enzymes. *Ann. Rev. Biochem. all. Res. India,* **7,** 1.
— (WITH BHARGAVA, P. N.). A new method of detection of cereal flours separately and in mixture by the "Agar-plate" method. *J. Indian Inst. Sci.*, **19,** A, 53.
1937. Uber pflanzenphosphatasen, Part I. Die phosphatase gekeimter Sojabohnen. *Z. für physiol. Chem.*, **245,** 185.
— (WITH SREENIVASAN, A.). Das amylase system des reiskornes wahrend des reifens undkeimens. *Biochem. Z.*, **289,** 155.
— (WITH BHARGAVA, P. N.). Differentiation of oils, by enzymic hydrolysis. Agar plate method and its application to the detection of adulteration of butter fat (Ghee). *Ind. Engng. Chem. anal. edn.*, **9,** 395.
— (WITH DASTUR, N. N.). Relative digestibilities of edible fats by castor seed and pancreatic lipases. *Indian J. med. Res.*, **25,** 427.
— The availability of phosphorus from Indian foodstuffs. *Indian J. med. Res.*, **25,** 869.
— Enzymes. *Ann. Rev. biochem all. Res. India,* **8,** 19.
— The stabilisation of vitamin C by pyrophosphate. *Indian J. med. Res.*, **25,** 443.

1938. The relation between vitamin C and plant phosphatases. *Proc. Soc. biol. Chem.*, **3,** 17.
— Vitamin C and phosphatases. *Nature,* London, **141,** 119.
— Uber Pflanzenphosphatasen, Part II. Bezeihung zwischen vitamin C und pflanzenphosphatasen. *Z. fur Physiol. Chem.*, **254,** 126.
— Die aktivierung von gewebsphosphatasen durch magnesium. *Z. fur Physiol. Chem.*, **254,** 117.
— (WITH SREENIVASAN, A.). Die anderung der amylolytischen wirksamkeit beim reiskorn wahrend der reifung und keimung. *Biochem. Z.*, **296,** 428.
— Further studies on the hydrolysis of starch by sweetpotato amylase. *J. Indian chem. Soc.*, **15,** 249.
— Enzymes. *Ann. Rev. biochem. all. Res. India,* **9,** 6.
— A highly sensitive test for vitamin C. *Mikrochem.*, **23,** 283.
— Photometric study of a new colorimetric method for vitamin C. *Proc. Soc. biol. Chem.*, **3,** 35.
— (WITH DOCTOR, N. S.). Pyrophosphate in the determination of vitamin C content of plant and animal tissues. *Indian J. med. Res.*, **26,** 165.
— The chemical composition and enzyme content of Indian honey. *Madras agric. J.*, **26,** 68.
1939. (WITH SREENIVASAN, A.). Studies on quality in rice. Part III. *In vitro* digestibilities of different of rice. *Indian J. agric. Res.*, **9,** 193.
— (WITH SHOURIE, K. L.). Serum phosphatase activity in rate fed on a poor South Indian diet variously supplemented. *Indian J. med. Res.*, **27,** 153.
— Indian gooseberries (*Phyllanthus emblica*) as source of Vitamin C. *Indian J. med. Res.*, **27,** 429.
— Enzymes. *Ann. Rev. biochem. all. Res. India,* **10,** 8.
— Interaction of vitamin C and tissue phosphatases. *Biochem. J.*, Cambridge, **33,** 309.
1940. Enzymes. *Ann. Rev. biochem. all. Res. India,* **11,** 1.
— (WITH KRISHNA MURTHY, P. V.). Co-existence of oxidising and protective mechanisms for vitamin C in plant tissues. *Nature,* London, **146,** 99.
— The availability of calcium and phosphorus in cereals. *Indian J. med. Res.*, **28,** 101.
— (WITH SHOURIE, K. L.). The protective action of tissues of scorbutic and normal guinea pigs against the oxidation of vitamin C and the nature of the protective mechanism. *Indian J. med. Res.*, **27,** 785.
1941. (WITH NAGANNA, B.). An adsorption method for the estimation of nicotinic acid content of animal tissues and blood. *Indian J. med. Res.*, **29,** 585.
— (WITH NAGANNA, B. *and* VENKATESAM, P.). Urinary excretion of nicotinic acid in pellagrins. *Indian med. Gaz.*, **76,** 208.
— (WITH NAGANNA, B.). An adsorption method for the estimation of nicotinic acid content of foodstuffs. *Indian J. med. Res.*, **29,** 125.
— (WITH KRISHNA MURTHY, P.V.). Further studies on the influence of pyrophosphate on the oxidation of vitamin C. *Indian J. med. Res.*, **29,** 71.
— (WITH KRISHNA MURTHY, P.V.). Studies in vitamin C oxidation. Part I. Co-existence of oxidising and protective factors in plants for vitamin C. *J. Indian chem. Soc.*, **18,** 7.
— (WITH KRISHNA MURTHY, P.V.). Studies in Vitamin C oxidation. Part II. Influence of various substances occurring in plant and animal tissues on the catalytic oxidation of Vitamin C. *J. Indian chem. Soc.*, **18,** 191.
— (WITH KRISHNA MURTHY , P.V.). Influence of purines, creatinine and creatine on the oxidation of vitamin C. *Nature,* London **147,** 59.
— Enzymes. *Ann. Rev. biochem. all. Res. India,* **12,** 1.
— The influence of vitamin C on the inactivation of enzymes by ultraviolet light. *J. Indian chem. Soc.*, **18,** 141.
— The relationship of vitamins to enzymes. **Ramalingareddy Shashtyabdapurti Commemoration Volume,** 161.
1942. On plant phosphatases. Part III. Glycero and pyrophosphatase and phytase activities of plant tissues. *Ann. Biochem. experiment. Med.*, **2,** 17.
— (WITH SARMA,M. L.). On plant phosphatase. Part IV. The occurrence of "free" and "bound" phosphatases in seeds. *Ann. Biochem. experiment. Med.*, **2,** 17.
— (WITH SESHAGIRI RAO, P.). The mechanism of B-amylase inhibition by vitamin C. *Proc. Indian Acad. Sci.*, **16,** B, 190.
— (WITH SESHAGIRI RAO, P.). On the nature of active group in papain. *Sci. Cult.*, **7,** 408.
— (WITH SESHAGIRI RAO, P.). On the nature of the active group in papain. *Sci. Cult.*, **7,** 510.
— Enzymes. *Ann. Rev. biochem. all. Res. India,* **13,** 1.
— Oxidation and stabilisation of vitamin C. *Sci. Cult.*, **8,** 111 & 159.
— (WITH KHORANA, M.L., *and* SARMA, M.L.). Investigations on the food value of fish and other marine products. Part I. The antipellagra vitamin (Nicotinic acid). *Indian. J. med. Res.*, **30,** 315.
— (WITH SESHAGIRI RAO, P.). War Chemotherapy : *The Antiseptic,* Special number on **"War Medicine and Surgery".** 1942 October.
— The anti-pellagra factor. *Indian med. Gaz.*, **77,** 98.

1943. Enzymes. *Ann. Rev. biochem. all. Res. India,* **14,** 1.
1944. (WITH SESHAGIRI RAO, P.). Urease activity and ascorbic acid. *Nature,* London, **153,** 253.
— Enzymes. *Ann. Rev. biochem. all. Res. India,* **15,** 1.
1945. (WITH DAS, R.). On plant phosphatases. Part V. Leaf phosphatase—distribution and general properties. *Ann. biochem. experiment. Med.,* **6,** 63.
— The food value of fish. *Sci. Cult.,* **10,** 275.
— (WITH DAS, R.). The elutreating effect of salts of carboxylic acids on the phosphatase alumina gel. *Sci. Cult.,* **11,** 149.
— Enzymes. *Ann. Rev. biochem. all. Res. India,* **16,** 1.
— (WITH RAHMAN, A.). Prothrombin in normal and pathological conditions. *Ann. biochem. experiment. Med.,* **5,** 17.
1946. (WITH DAS, R., *and* RAO, P.L.N.). A micro method for the detection of phosphatases by "agar-plate" method. *Sci. Cult.,* **11,** 700.
— Enzymes. *Ann. Rev. biochem. all. Res. India,* **17,**1.
— (WITH SESHAGIRI RAO, P.). The inhibitors of enzymatic and cupric ion oxidation of vitamin C. *Proc. Indian Acad. Sci.,* **24,** 264.
— (WITH REDDY, K.K.). A shortened procedure for estimating vitamin B_1 in foodstuffs. *Sci. Cult.,* **16,** 285.
— Fortification of food grains. *Proc. Soc. biol. Chem.,* **5,** 3.; *Mysore agric. J.,* **23,** 115.
— (WITH KUPPUSWAMY, S. *and* SUBRAHMANYAN, V.). Oil seed cakes as supplements to South Indian Rice diet. *Sci. Cult.,* **12,** 249.
— (WITH KUPPUSWAMY, S., *and* SUBRAHMANYAN, V.). Processed oil seeds and seed cakes as articles of human food. *Sci. Cult.,* **12,** 339.
1947. (WITH SESHAGIRI RAO, P.). Further studies on the mechanism of B-amylase inhibition by vitamin C. *Proc. Indian Acad. Sci.,* **28,** B, 71.
— (WITH REDDY, K.K.). Influence of variety, manuring and germination on vitamin B_1 content of groundnut (*Arachis hypogea*). *Curr. Sci.,* **16,** 285.
— (WITH KUPPUSWAMY, S. *and* SUBRAHMANYAN, V.). Predigested protein foods. *Indian med. Gaz.,* **82,** 63.
— (With CHAK, I.M.). Effect of carbondioxide and ultrafiltration on plasma prothrombin. *Nature,* London, **159,** 878.
— (WITH CHAK, I.M.). Blood clotting factor in castor seed. *Sci. Cult.,* **12,** 598.
1948. (WITH CHAK, I.M.). Regeneration of prothrombin activity by carbondioxide. *Nature,* London, **161,** 354.
— (WITH CHAK, I.M., *and* PEREIRA, J.F.). *In vitro* effect of penicillin on prothrombin activity of bovine plasma. *Nature,* London, **162,** 930.
Some recent developments in new foods and treatment of malnutrition. *J. Indian med. Assoc.,* **17,** 165.
— (WITH REDDY, K.K., *and* DAS, R.). Thiaminase system in freshwater Mussel (*Lamellidens marginalis*). *Enzymologia,* Amsterdam, **12,** 238.
— (WITH LAKSHMANAN, S., *and* SRI RAM, J.) The preparation of amylase by thymol precipitation method. *Curr. Sci.,* **12,** 366.
1949. (WITH REDDY, K.K.). The nutritive and vitamin value of groundnut. Part I. Vitamin B_1 content of groundnut (*Arachis hypogea*) as affected by variety. *Proc. Indian Acad. Sci.,* **29,** 59.
— (WITH REDDY, K.K.). The nutritive and vitamin value of groundnut, Part II. The presence of free and combined forms of vitamin B_1 in groundnut (*Arachis hypogea*). *Proc. Indian Acad. Sci.,* **29,** 65.
— (WITH REDDY, K.K.). The nutritive and vitamin value of groundnut. Part III. Physiological availability of vitamin B_1 in groundnut *Arachis hypogea. Proc. Indian Acad. Sci.,* **29,** 70.
— (WITH REDDY, K.K.). The nutritive and vitamin value of groundnut, Part IV. Influence of germination on the vitamin B_1 content of groundnut (*Arachis hypogea*). *Proc. Indian Acad. Sci.,* **29,** 75.
— (WITH REDDY, K.K.). The nutritive and vitamin value of groundnut, Part V. Influence of manuring on the Vitamin B_1 content of groundnut (*Arachis hypogea*). *Proc. Indian Acad. Sci.,* **29,** 79.
— (WITH KUPPUSWAMY, S., *and* SUBRAHMANYAN, V.). Supplementary value of oil seed cakes to South India diet. *Indian J. med. Res.,* **37,** 41.
— (WITH DAS, R.). On plant phosphatase, Part VI. Purification and chemical nature of leaf phosphatase. *Ann. Biochem. experiment. Med.,* **9,** 113.
— (WITH REDDY, K.K.). Purification and separation of the two thiaminases in fresh water mussel (*Lamellidens marginalis*). *Enzymologia,* **13,** 281.
— (WITH SRI RAM, J.). Influence of vitamin C on phosphorylase. *Curr. Sci.,* **18,** 440.
— (WITH KRISHNAMURTHY, C.R.). Preparation, purification and composition of pectins from Indian fruits and vegetables. *Proc. Indian Acad. Sci.,* **20,** 155.
— (WITH SAHADEO, M.A. *et al.*). Vitamin C content of lucerne and the factors controlling its stability. *Proc. Indian Acad. Sci.,* **31,** 331.

— (WITH SESHAGIRI RAO, P., *and* RAHMAN, A.). Influence of vitamin C and oxidising agents on prothrombin. *Proc. Indian Acad. Sci.*, **30,** 316.
1950. Distribution of the protective factors for vitamin C in fractions of liver homogenates of the rat. *Nature*, London, **166,** 44.
1951. (WITH DAS, R.). Screening effect of vitamin C on the inactivation of leaf phosphatase by ultraviolet light. *Science* (U.S.A.), **114,** 131.
— (WITH PRASAD, A.L.N.). Enzymes. *Ann. Rev. biochem. all. Res.*, **22,** 28.
— Groundnut as raw material for food Industries. *Oil & Oil Seeds J.*, **4,** 16.
— (WITH PRASAD, A.L.N.). Detection of enzymes by Agar-Plate method and its application to paper chromatography. *Nature*, London, **167,** 859.
— (WITH PRASAD, A.L.N.). Separation of enzymes by paper chromatography. *Nature*, London, **168,** 786.
— Circular paper chromatography for the separation of amino acids. *Curr. Sci* , **20,** 295.
1952. (WITH SAROJA, K.). *p*H activity relationship of the Alpha-and Beta-amylases of resting and germinated barley and ragi (*Eleusine coracana*). *J. Indian Inst. Sci.*, **35,** 99.
— (WITH SESHAGIRI RAO, P.). Interaction of vitamin C and urease. *Proc. Indian Acad. Sci.*, B, **35,** 132.
— (WITH SRI RAM, J.). Starch synthesising enzymes of green gram (*Phaseolus radiatus*). Arch. *Biochem. Biophys.* (*U.S.A.*), **38,** 231.
— (WITH RADHAKRISHNAN, A.N., *and* VAIDYANATHAN, C.S.). Transaminase activity in plants. *J. Indian Inst. Sci.*, **34,** 305.
— *Food and Population and Development of Food Industries in India.* C.F.T.R.I., Mysore p. 99, Wesley Press and Publishing House, Mysore.
— (WITH LAL, B.M., *and* RAJAGOPALAN, R.). Utilisation des graines oleagines pour L'Alimentation humaine. *Oleaginex* (*Paris*), **7,** 637.
— (WITH RAMAKRISHNAN, T., *and* PILLAI, N.C.). The occurrence of a blood-anticoagulant factor in the latex of *Carica papaya*. *Curr. Sci.*, **21,** 251.
— (WITH RAMA RAO, R.). Free amino acid pattern of blood normal and malarial chick infected with *p*-gallinaceum. *Indian J. Malariol.*, **6,** 411.
— (WITH PRASAD, A.L.N. *et al.*). A technique for the identification and separation of enzymes by paper chromatography. *Biochem. J.*, **51,** 123.
— (WITH RAO, N.A.N.). A technique for the identification of amino acids separated by circular paper chromatography. *Nature*, London, **169,** 923.
— (WITH KRISHNAMURTHY, K., *and* VENKITASUBRAMANIAM, T.A.). Separation and identification of amino acids from protein hydrolysates by circular paper chromatography, *Curr. Sci.*, **21,** 11, (1952).
— (WITH KRISHNAMURTHY, K., *and* VENKITASUBRAMANIAM, T.A.). Quantitative determination of amino acids separated by circular paper chromatography. *Curr. Sci.*, **21,** 44.
— (WITH KRISHNAMURTHY, K. *and* VENKITASUBRAMANIAM, T.A.). Circular Paper Chromatographic analysis of the amino acids of tea and coffee infusions. *Curr. Sci.*, **21,** 133.
— (WITH RAO, N.A.N.). Circular paper chromatography, Part I-A technique for the separation and identification of amino acids. *J. Indian Inst. Sci.*, **34,** 95.
— (WITH KRISHNAMURTHY, K., *and* VENKITASUBRAMANIAM, T.A.). A simple paper chromatographic technique for amino acid analysis of blood. *Lancet*, **20,** 562.
— (WITH KRISHNAMURTHY, K., *and* VENKITASUBRAMANIAM, T.A.). A simple paper chromatographic technique for amino acid analysis of blood. *Lancet*, **20,** 562.
— (WITH RADHAKRISHNAN, A.N., *and* VAIDYANATHAN, C.S.). Some factors influencing the quantitative determination of amino acids separated by circular paper chromatography. *Anal. Chem. U.S.A.*, **24,** 1677.
— (WITH RADHAKRISHNAN, A.N., *and* VAIDYANATHAN, C.S.). A simple paper chromatographic method for the study of transamination reactions. *Nature*, London, **170,** 1025.
— (WITH KRISHNAMURTHY, K., *and* VENKITASUBRAMANIAM, T.A.). Preservation of paper chromatograms. *Curr. Sci.*, **21,** 252.
— (WITH RADHAKRISHNAN, A.N., *and* VAIDYANATHAN, C.S.). Circular paper chromatography, Part VI—The quantitative determination of amino acids. *J. Indian Inst. Sci.*, **35,** 145.
— (WITH NAGABHUSHANAM, A.). Sodium 1:2 Napthoquinone-3-sulphonate as reagent for identification of amino acids and peptides and for quantitative estimation of proline and hydroxyproline separated on paper chromatograms. *Naturwiss.* **39,** 548.
— (WITH KRISHNASWAMY, N.). The use of synthetic ion exchange resins for the isolation and separation of amino acids. *Sci. Cult.*, **17,** 369.
— (WITH PRASAD, A.L.N.). Chromatography. *Ann. Rev. biochem. All. Res.*, **23,** 1.
— (WITH GOPALAKRISHNAN, K.S., *and* RADHAKRISHNAN, A.N.). Proline and hydroxyproline in leaves. *Nature*, London, **170,** 579.
— (WITH KRISHNASWAMY, P.R.). The ocurrence of alpha-aminobutyric acid and glutamic acid decarboxylase in Red Yeast (*Rhodotorula glutinis*). *Curr. Sci.*, **22,** 143.
1953. (WITH KALYANKAR, G.D.). Non-enzymatic transamination between alpha-amino acid and keto acids. *Naturwiss.*, **40,** 224.

— (WITH VAIDYANATHAN, C.S.). Studies on arginase, Part I. Arginase from field beans (*Dolichos lablab*), general properties and the effect of metallic ions. *Enzymologia*, **16,** 167.
— (WITH NARASIMHA RAO, P.L. *et al.*). Enzymic synthesis of oligosaccharides by *Penicillium chrysogenum* Q 176. *Naturwiss.*, **40,** 484.
— (WITH RAMA RAO, P.B., *and* RAJAGOPALAN, R.). Some studies on the destruction of amino acids in proteins caused by autoclaving in presence of glucose. *Food Res.* (*U.S.A.*), **18,** 217.
— (WITH GANGADHARAM, P.R.J. *et al.*). Studies on the antitubercular activity of sesamin. *J. Indian Inst. Sci.*, **35,** 69.
— (WITH MISS TARA RAO,). Circular paper chromatography. Part III-Rf values of amino acids and peptides. *J. Indian Inst. Sci.*, **35,** 77.
— (WITH KRISHNAMURTHY, D.V., *and* NARASIMHA RAO, P.L.). Circular paper chromatography. Part IV-Separation of organic acids. *J. Indian Inst. Sci.*, **35,** 93.
— (WITH MISS TARA RAO). Circular paper chromatography. Part V-The separation, identification and quantitative determination of urea with application to human urine. *J. Indian Inst. Sci.*, **35,** 137.
— (WITH RAO, N.A.N.). Circular paper chromatography. Part VII-A technique for the separation and estimation of "Overlapping amino acids". *J. Indian Inst. Sci.*, **35,** 343.
— (WITH RAO, N.A.N.) Separation and estimation of overlapping amino acids by circular paper chromatography using different solvent mixtures. *Curr. Sci.*, **22,** 114.
— Filter paper disc chromatography. *Nature*, London, **171,** 159.
— (WITH KRISHNASWAMY, P.R. *et al.*). Separation and identification of the degradation products of purines and nucliec acids on acid hydrolysis by circular paper chromatography. *Experentia*, **9,** 296.
— (WITH NIGAM, V.N.). Separation of simple saccharides and oligosaccharides by circular paper chromatography. *Naturwiss.*, **40,** 343.
— (WITH NIGAM, V.N., *and* SAROJA, K.). Application of circular paper chromatography to the study of the mechanism of amylolysis. *Naturwiss.*, **40,** 484.
— A simple paper chromatographic method for the separation and quantitative determination of Vitamins B_1 and B_2. *Curr. Sci.*, **22,** 373.
— (WITH NAGABHUSHANAM, A.). A simple paper chromatographic method for the determination of lactose of milk. *Curr. Sci.*, **23,** 221.
— (WITH RADHAKRISHNAN, A.N.). Chromatography. *Ann. Rev. biochem. all. Res.*, **24,** 1.
— (WITH KALYANKAR, G.D., *and* VAIDYANATHAN, C.S.). Photolysis of amino acids in sunlight in presence of the photosensitiser titanium dioxide. *Naturwiss.*, **40,** 440.
1954. (WITH RAMASARMA, T., *and* SRI RAM, J.). Phosphoglucomutase of green gram (*Phaseolus radiatus*). *Arch. Biochem. Biophys.*, **53,** 167.
— (WITH NIGAM, V.N., *and* SRINIVASAN, K.S.). Synthesis of oligosaccharides during enzymatic hydrolysis of cellobiose by *Aspergillus flavus*. *J. Indian Inst. Sci.*, **36,** 259, (1954).
— (WITH NIGAM, V.N., *and* SRINIVASAN, K.S.). Enzymic synthesis of oligosaccharides from sucrose and lactose by *Aspergillus flavus*. *J. Indian Inst. Sci.* **36,** 259.
— The Karyolytic factor in the serum of rats injected with colchicine. *Nature*, London, **165,** 1021.
— (WITH NIGAM, V.N.). Circular paper chromatography, Part VIII-Separation, identification and quantitative estimation of sugar and oligosaccharides. *J. Indian Inst. Sci.*, **36,** 49.
— Preparative circular paper chromatography. *Nature* London, **173,** 1194.
— (WITH RADHAKRISHNAN, A.N.). The isolation of L-allo-hydroxyproline form sandal (*Santalum Album Linn.*). *Biochem. J.*, **58,** 57.
— (WITH KALYANKAR, G.D., *and* VAIDYANATHAN, C.S.). Photolysis of methionine in presence of photocatalysts. *Naturwiss*, **41,** 88.
— (WITH KRISHNASWAMY, P.R.). The effect of biotin on the utilisation of glutamic acid by yeast. *J. scient. & ind. Res.*, **13,** 110.
— (WITH KRISHNASWAMY, P.R.). Studies on the synthesis of riboflavin by a mutant yeast (Sacchzromyces cerevisia). *Bact.* (*USA*), **67,** 309.
1955. (WITH SAROJA, K., *and* VENKATARAMAN, R.). Transglucosidation in *Penicillium chrysogenum* Q. 176. Isolation and identification of the oligosaccharides. *Biochem. J.*, **60,** 399.
— (WITH NAGABHUSHANAM, A. *et al.*). Synthesis of oligosaccharides from maltose by rat liver. *Science* (*USA*), **121,** 898.
— Transferases synthesising oligosaccharides. *Soc. biol. Chem.*, **Siiver Jubilee Volume**).1.
— (WITH BALAKRISHNAN, S., *and* RAJAGOPALAN, R.).The present state of knowledge regarding biosynthesis of B-complex vitamins. *Indian med. Gaz.*, **65,** 7.
— (WITH PILLAI, N.C., *and* VAIDYANATHAN, C.S.). A blood anticoagulant factor from the latex of *Carica papaya*. *Proc. Indian Acad. Sci.*, **42,** B, 316.
— Circular paper chromatography. Part IX-Preparative circular paper chromatography for large scale separation and isolation of substances. *J. Indian Inst. Sci.*, **37,** 1.
— A simple paper chromatographic method for the study of serum protein patterns in health and disease. *Experentia*, **11,** 165.

— (WITH PARIHAR, D.B.). Flowing chromatography on circular paper pack. *Nature,* London, **175,** 304.

— (WITH BALIGA, B.R. *et al.*). A simple method for desalting biological fluids for chromatography. *J. Indian Inst. Sci.,* **37,** 18.

— (WITH BALAKRISHNAN, S.). Circular paper chromatographic method for the estimation of thiamine and riboflavin in multivitamin preparations. *Anal. Chem.* (*U.S.A.*), **17,** 1178.

— (WITH RAMACHANDRA, B.V., *and* DASTUR, N.N.). Application of circular paper chromatography method for the detection of adulteration of milk. *Indian J. Dairy Sci.,* **8,** 83.

— (WITH RAVINDRA NATH *and* COHLY, M.A.). A microelectrophoretic study of the complex formation of (RNA) bovine plasma albumin (BPA) and ribose nucleic acid. *J. Indian Inst. Sci.,* **37,** 163.

— (WITH KALYANKAR, G.D., *and* VAIDYANATHAN, C.S.). The action of hydrogen peroxide on amino acids in presence of iron salts and its bearing on photolysis of amino acids. *Experentia,* **11,** 348.

— (WITH VAIDYANATHAN, C.S., *and* KALYANKAR, G.D.). The non-enzymatic transamination and decarboxylation of amino acids in presence of cellulose. *J. Indian Inst. Sci.,* **37,** 304.

— (WITH VAIDYANATHAN, C.S., *and* KALYANKAR, G.D.). The photochemical degradation of alpha-and beta-alanine and its importance in soil chemical processes. *Proc. natn. Acad. Sci. India,* Allahabad. **24,** A, 286.

— (WITH RADHAKRISHNAN, A.N., *and* VAIDYANATHAN, C.S.). Nitrogenous constituents in plants: Part-free amino acids in leaves and leguminous seeds. *J. Indian Inst. Sci.,* **37,** 178.

— (WITH BALASUNDARAM, S., *and* SRINIVASAN, K.S.). Stabilization of nitrogen, an aspect of manuring of alkaline cotton soils. *Indian Cot. Grow. Rev.,* **9,** 3.

1956. (WITH RAMASARMA, T.). Phosphoglucose Isomerase of green gram (*Phaseolus radiatus*). *Arch. Biochem. Biophys.* (*U.S.A.*), **62,** 91.

— (WITH RAMASARMA, T.). Glycolytic enzymes in green gram (*Phaseolus radiatus*). *Curr. Sci.,* **25,** 215.

— (WITH KRISHNASWAMY, P.R.). Glutamic acid decarboxylase in *Rhodotorula glutinis. Biochem. J.,* **62,** 301.

— (WITH PILLAI, N.C., *and* VAIDYANATHAN, C.S.). A blood anticoagulant factor from the latex of *Carica papaya. Proc. Indian Acad. Sci.,* **43,** B, 316.

— (WITH PILLAI, N.C.). Multiple haemoglobins in the blood of animals. *Nature,* London, **178,** 1057.

— Perchloric acid as reagent for tryptophane, tyrosine and hydroxyproline in paper chromatography. *Naturwiss.,* **43,** 18.

— Zone electrophoresis of serum proteins in agar gel. *Naturwiss.,* **43,** 36.

— A simple agar-electrophoresis apparatus and technique. *Naturwiss.,* **43,** 232.

— Agar-electrophoresis on cellophane and polyster films. *Naturwiss.,* **43,** 226.

— (WITH PILLAI, N.C.). Agar-electrophoresis of haemoglobins. *Curr. Sci.,* **25,** 138.

— Agar-electrophoresis of serum proteins on cellophane and polyester films. *J. Lab. clin. med.,* (*U.S.A.*), **48,** 775.

— Agar-electrophoresis, Part I. A simple clinical method for the analysis of serum proteins. *J. Indian Inst. Sci.,* **38,** 170.

— Demonstration of micro-heterogeneity of blood serum proteins by two-stage agar electrophoresis. *Naturwiss.* **43,** 448.

— Electrophoresis in medical research. *J. Mysore med. Assoc.,* **21,** 57.

— (WITH RAMASARMA, T., *and* NIGAM, V.N.). Sucrose formation in green gram (*Phaseolus radiatus*). *Proc. Soc. biol. Chem.* (*India*), **15,** 31.

1957. (WITH KRISHNASWAMY, P.R., *and* APPAJI RAO, N.). On the occurrence of flavokinase activity in plants. *Nature,* London, **179,** 1134.

— (WITH RAVINDRANATH). Physico-chemical investigations on indigenous seed proteins: Part I. Studies on the solubilization of nitrogenous constituents of *Sesamum indicum* and characterisation of its proteins by electrophoresis. *J. scient. ind. Res.,* **16,** C, 5.

— (WITH RAVINDRA NATH) Physico-chemical studies on indigenous seed proteins: Part II Practionation, isolation and electrophoretic characterization of sesame globulins. *J. scient ind. Res.,* **16,** C, 51.

— Two-dimentional agar electrophoresis of serum mucoproteins. *Proc. Soc. biol. Chem.* (*India*), **16,** 17.

— Recent developments in technique of electrophoresis. *Proc. Soc. biol. Chem.* (*India*), **16,** 17.

— (WITH KRISHNASWAMY, P.R., *and* APPAJI RAO, N.). The flavin nuclectide synthesising enzymes in yeasts and plants. Conference on flavin enzymes. *Nagoya* (*Japan*), p. 4.

1958. (WITH KRISHNASWAMY, P.R., *and* APPAJI RAO, N.). Studies on riboflavin metabolism in plants. *Symp. Recent Adv. Plant Metabolism,* **1,** 1.

— (WITH KRISHNASWAMY, P.R., *and* APPAJI RAO, N.). Studies on plant flavokinase. *Biochem. J.*, **70,** 66.

— (WITH APPAJI RAO, N., *and* DEB, A.K). The occurrence of enzymes synthesizing flavin mononucleotide and flavin adenine dinucleotide in milk. *Naturwiss.*, **14,** 340.