
COMMUNICATION AND COLLABORATIVE RESEARCH PATTERN OF PROFESSOR RAMACHANDRAN : A SCIENTOMETRIC PORTRAIT

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G. N. Ramachandran has worked in various fields in anomalous scattering, and the phase problem, the analysis of the structure of fibres, and the conformational analysis of macromolecular structures. He is considered to be one of the founders of the rapidly developing field of molecular biophysics, his contributions are mainly to the theory of molecular structure of biopolymers in relation to their biological activities. In his 49 years of productive life, he has collaborated with 81 colleagues and students and has published 304 papers during 1942 – 1990. The highest collaboration coefficient is 0.86. He has the highest collaboration with V. Sasisekharan (18) and R. Srinivasan (15). The core journals, which publishing his papers were: *Proceedings of the Indian Academy of Sciences*, *Acta Crystallographica*, *Current Science*, *Nature* and *Biopolymers*.

INTRODUCTION

Prof. Gopalamudram Narayana Iyer Ramachandran born in October 8, 1922 at Ernakulam, a town in Kerala state (the southwestern tip of India), received a master's degree in physics from Madras University in 1942. He joined Indian Institute of Science, Bangalore, and carried out research under the able guidance of Nobel Laureate Sir C. V. Raman. He obtained a D.Sc. degree from Madras University and later a Ph.D. from Cambridge University. He was on the faculty of the dept. of Physics, Indian Institute of Science, Bangalore, until about 1952 when he moved to Madras University, where a major portion of his research in Crystallography and Biophysics was performed.

In 1970 he returned to Indian Institute of Science and founded the Molecular Biophysics Unit. It is to his credit that he was instrumental in putting the Molecular Biophysics unit and the dept. of Physics, University of Madras (later known as Center of Advanced Study in Biophysics and Crystallography) on the international scientific map. While at Madras and Bangalore, he had the full support of Dr. Sir A. Lakshmanaswamy Mudaliar, Madras University, and Prof. Satish Dhawan, Director of Indian Institute of Science.

Ramachandran is considered to be one of the founders of the rapidly developing field of Molecular Biophysics. His contributions are mainly to the theory of Molecular Structure of biophysics in relation to their biological activities. Between 1954-56, along with G. Kartha, he put forward the triple helical structure of collagen.

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Attempts to revise the details of this structure from theory led to the enunciation of the so-called Ramachandran Plot for the dihedral angles (Φ , ψ) for two connecting analogues. This was a turning point in the evolution of the theory of biopolymer conformation and has found application in almost all branches of biochemistry and molecular biology. It has been extended to nucleic acid and polysaccharides conformation in his laboratories. He and his group have developed methods of using anomalous dispersion of X-rays for solving the phase problem. His work on Fourier transformations led to the formulation of the convolution technique for axial tomography. His work with A.V. Laxminarayanan has been acclaimed as the starting point for the development of CAT scan technique in radiography and later to magnetic resonance imaging.

Ramachandran was a visiting professor at the University of Michigan from 1965 to 1966 and was associated with the University of Chicago from 1967 to 1977. During that time, he did some exciting work on three-dimensional image reconstruction from radiographs and electron micrographs, which became applicable to computer-aided tomography. Prof. Ramachandran deservedly received many awards and honours, most notably the Shanti Swarup Bhatnagar Award for Physics in India and the Fellowship of the Royal Society of London. Very recently, The International Union of Crystallography honoured him with its prestigious Ewald Prize for his outstanding contributions to crystallography¹.

METHODOLOGY

A complete bibliography of his research publication from 1942-1990 has been catalogued and standard bibliometric fields were analysed by normal count procedure for various domains such as authors and journals. The methodology as suggested by Sangam and Savanur², Kademani and Kalyane³, has been used.

RESULTS AND DISCUSSIONS

Publication productivity

In table 1 the total number of publications are 304 scientific papers, books, chapters in books, edited books, monographs and reviews, conference proceedings and mathematical reports. During 1942-1990, these includes 147 (48.35%) single authored and 157 (51.64%) multi-authored papers. The multi-authored papers includes: two authored

(103), three- authored (39), four- authored (8), five- authored (2), six- authored (2) and seven- authored (3). The first paper was published in 1942 at an early age of 21.

Quinquennial period-wise trends in publications single authored papers, multi-authored and cumulative number of papers along with collaborative coefficients are seen in figure

1. The author did not have any publications in 1977. His highest productivity was in the year of 1963 with the output of 15 papers (age 41), followed by 13 papers in 1965 (age 43), and 12 papers each in 1966, 1980 and 1987 (ages 44, 58 and 65) respectively, and 11 papers each in 1967, 1968, 1970, 1981 and 1985 (ages 45, 46, 48, 59 and 63) respectively. Thus 41st and 43rd to 46th years of his life were most productive. The fifty-percentile productivity life was 26 at 45 years of age. The productivity life of the author spans 49 years starting from age 21. Hence productivity coefficient⁴ amounts 0.53.

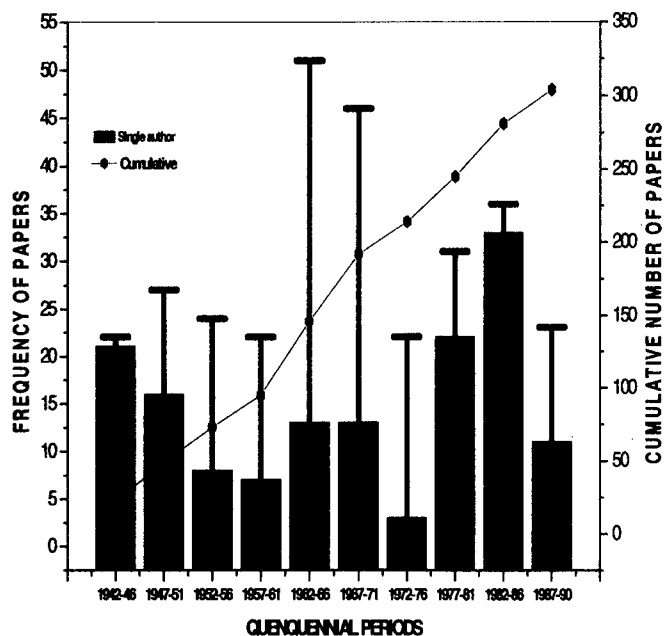


Figure 1. Productivity and collaboration of Prof. G.N. Ramachandran

Table 1 Single and multiple authored publications.

APL YEAR	1 aut	2 aut	3 aut	4 aut	5 aut	6 aut	7 aut	MT	TP	AA
1 1942	1	-	-	-	-	-	-	0	1	21
2 1943	6	-	-	-	-	-	-	0	6	22
3 1944	6	-	-	-	-	-	-	0	6	23
4 1945	3	-	-	-	-	-	-	0	3	24
5 1946	5	1	-	-	-	-	-	1	6	25
6 1947	9	-	-	-	-	-	-	0	9	26
7 1948	1	-	1	-	-	-	-	1	2	27
8 1949	2	-	1	-	-	-	-	1	3	28
9 1950	1	2	-	-	-	-	-	2	3	29
10 1951	3	7	-	-	-	-	-	7	10	30
11 1952	4	3	-	-	-	-	-	3	7	31
12 1953	1	1	-	-	-	-	-	1	2	32
13 1954	1	3	-	-	-	-	-	3	4	33
14 1955	1	5	1	-	-	-	-	6	7	34
15 1956	1	3	-	-	-	-	-	3	4	35
16 1957	1	4	-	-	-	-	-	4	5	36
17 1958	-	1	-	-	-	-	-	1	1	37
18 1959	-	2	-	-	-	-	-	2	2	38
19 1960	4	3	-	-	-	-	-	3	7	39
20 1961	2	5	-	-	-	-	-	5	7	40
21 1962	2	5	1	-	-	-	-	6	8	41
22 1963	4	4	6	-	-	1	-	11	15	42
23 1964	1	-	2	-	-	-	-	2	3	43
24 1965	5	6	2	-	-	-	-	8	13	44
25 1966	1	4	2	2	-	-	3	11	12	45
26 1967	4	2	4	1	-	-	-	7	11	46
27 1968	5	5	1	-	-	-	-	6	11	47
28 1969	2	2	1	-	-	-	-	3	5	48
29 1970	1	6	2	1	1	-	-	10	11	49
30 1971	1	3	3	-	-	1	-	7	8	50
31 1972	2	2	1	-	-	-	-	3	5	51
32 1973	-	1	4	2	-	-	-	7	7	52
33 1974	-	-	1	1	-	-	-	2	2	53
34 1975	1	-	3	-	-	-	-	3	4	54
35 1976	-	4	-	-	-	-	-	4	4	55
37 1978	1	1	-	-	-	-	-	1	2	57
38 1979	6	-	-	-	-	-	-	0	6	58
39 1980	8	3	1	-	-	-	-	4	12	59
40 1981	7	2	1	-	1	-	-	4	11	60
41 1982	6	-	-	-	-	-	-	0	6	61
42 1983	5	-	1	-	-	-	-	1	6	62
43 1984	5	-	-	-	-	-	-	0	5	63
44 1985	9	2	-	-	-	-	-	2	11	64
45 1986	8	-	-	-	-	-	-	0	8	65
46 1987	6	6	-	-	-	-	-	6	12	66
47 1988	1	5	1	-	-	-	-	6	7	67
48 1989	2	-	-	-	-	-	-	0	2	68
49 1990	2	-	-	-	-	-	-	0	2	69
Total		147	103	39	8	2	2	3	157	304

COLLABORATION

Communication and collaboration between researchers are of great importance in the development of subject areas. In order to measure the collaborative research pattern, a simple indicator called Collaboration Coefficient⁵ (number of collaborative papers divided by total number of papers) is used. Highest collaboration coefficient 0.86 was during 1972-1976 further 51.64 percent of his papers were collaborative.

During the past 49 years Prof. G. N. Ramachandran had collaborated with 81 researchers as seen in table 2. The publication productivity of his research group in chronological order is depicted in figure 2. In table 2 it has been observed that Prof. V. Sasisekharan has collaborated the highest i.e. 18 published research papers from the year 1956-1974, Prof. R. Srinivasan has 15 papers form the year 1959-1970, Professor Ramakrishnan has collaborated 14 papers from the year 1962-1975, Professors Laxminarayanan and Thanaraj had collaborated each 13 papers, from 1966-1973 and 1980-1987 respectively, and Prof. R. Chandrasekharan had collaborated 11 papers from 1967-1973. Researchers collaborated with Prof. G. N. Ramachandran single author, two author etc., as given in table 2. The authorship credit counts for 82 authors at 545, each collaborating author being given one authorship credit for each paper, Prof. G. N. Ramachandran to his credit has 55.7 percentage of total authorship credit.

Table 2. Authorship credit of researchers collaborating with Ramachandran in chronological order

APL	1 aut	2 aut	3 aut	4 aut	5 aut	6 aut	7 aut	Total CAC	Period
1 Ramachandran, G. N.	147	124	38	8	2	2	3	304	1942-1990
2 Chandrasekharan, V.	-	3	-	-	-	-	-	3	1946-1951
3 Wooster, W. A.	-	3	2	-	-	-	-	5	1948-1951
4 Lang, A.	-	-	2	-	-	-	-	2	1948-1949
5 Hirsch, P. B.	-	1	-	-	-	-	-	1	1950
6 Radhakrishnan, A.	-	1	-	-	-	-	-	1	1951
7 Thatachary, Y. T.	-	1	1	-	-	-	-	2	1951-1962
8 Vedam, K.	-	1	-	-	-	-	-	1	1951
9 Radhakrishnan, T.	-	1	-	-	-	-	-	1	1952
10 Ramaseshan, S.	-	4	-	-	-	-	-	4	1952-1961
11 Kartha, G.	-	5	-	-	1	-	-	6	1952-1963
12 Ambady, G. K.	-	2	-	-	-	-	-	2	1954-1955
13 Amrithalingam, V.	-	1	-	-	-	-	-	1	1955
14 Krishnan, G.	-	-	1	-	-	-	-	1	1955
15 Santhanam, M. S.	-	2	1	-	-	-	-	3	1955-1957
16 Raman, S.	-	3	-	-	-	-	-	3	1956-1962
17 Sasisekharan, V.	-	10	6	1	1	-	-	18	1956-1974
18 Chandrasekharan, K. S.	-	1	1	-	-	-	-	2	1957-1967
19 Lonappan, M. A.	-	1	-	-	-	-	-	1	1957
20 Krishnamurthy, E. V.	-	1	-	-	-	-	-	1	1958
21 Srinivasan, R.	-	8	6	-	1	-	-	15	1959-1970
22 Vembu, S.	-	1	-	-	-	-	-	1	1961
23 Dweltz, M. E.	-	1	-	-	-	-	-	1	1962
24 Parthasarathy, R.	-	3	1	-	-	-	-	4	1962-1963
25 Ramakrishnan, C.	-	3	8	3	-	-	-	14	1962-1975
26 Venkataraman, S.	-	1	-	-	-	-	-	1	1962
27 Iyer, R. R.	-	1	-	-	-	-	-	1	1963
28 Bhat, H. B.	-	-	-	-	1	-	-	1	1963
29 Nair, P. M.	-	-	-	-	1	-	-	1	1963
30 Raghavan, V. K. M.	-	-	-	-	1	-	-	1	1963
31 Venkataraman, K.	-	-	-	-	1	-	-	1	1963
32 Mallikarjunan, M.	-	-	1	-	-	-	-	1	1963
33 Sarma, R.	-	-	3	-	-	-	-	3	1963
34 Parthasarathy, S.	-	3	3	-	-	-	-	6	1964-1969
35 Subramaniam, E.	-	-	1	-	-	-	-	1	1964
36 Venkatchalam, C. M.	-	6	3	-	-	-	-	9	1965-1970
37 Laxminarayanan, A. V.	-	4	3	5	-	1	-	13	1966-1973
38 Edsall, J. T.	-	-	-	-	-	-	3	3	1966
39 Flory, P. J.	-	-	-	-	-	-	3	3	1966
40 Kandrew, J. C.	-	-	-	-	-	-	3	3	1966
41 Liquori, A. M.	-	-	-	-	-	-	3	3	1966

42	Nemethy, G.	-	-	-	-	-	3	3	451	1966
43	Hcheraga, H. A.	-	-	-	-	-	3	3	454	1966
44	Mazumdar, S. K.	-	-	-	1	1	-	2	456	1966-1970
45	Venkatesan, K.	-	-	-	1	1	-	2	458	1966-1971
46	Krimm, S.	-	-	-	1	-	-	1	459	1966
47	Chandrasekharan, R.	-	5	4	2	-	-	11	470	1967-1973
48	Rao, V.S.R.	-	-	-	1	-	-	1	471	1967
49	Sundararajan, P. R.	-	-	-	1	-	-	1	472	1967
50	Doyle, B. B.	-	-	-	1	-	-	1	473	1968
51	Blout, E. R.	-	-	-	1	-	-	1	474	1968
52	Sarathy, K. P.	-	1	2	-	-	-	3	477	1968-1973
53	Kalyanaraman, A. R.	-	-	-	1	-	-	1	478	1968
54	Balasubramanian, R.	-	-	-	2	1	1	4	482	1970-1971
55	Chidambaram, R.	-	-	-	4	-	-	4	486	1970-1971
56	Dow, J.	-	-	-	-	-	1	1	487	1970
57	Jensen, L. H.	-	-	-	-	1	-	1	488	1970
58	Tgoni, G.	-	-	-	1	1	-	2	490	1970-1971
59	Kopple, K.	-	-	-	1	-	-	1	491	1971
60	Sabesan, M. N.	-	-	-	-	-	1	1	492	1971
61	Ramani, R.	-	1	-	-	-	-	1	493	1972
62	Ramachandran, G.	-	-	-	1	-	-	1	494	1972
63	Tagara, S. G.	-	-	-	1	-	-	1	495	1972
64	Bansal, M.	-	2	4	-	-	-	6	501	1973-1978
65	Bhatnagar, R. S.	-	-	-	1	-	-	1	502	1973
66	Mohanakrishnan, P.	-	-	-	1	-	-	1	503	1973
67	Kolaskar, A. S.	-	1	4	1	-	-	6	509	1973-1974
68	Pandya, U. V.	-	-	-	1	-	-	1	510	1973
69	Narayan, R.	-	-	-	1	-	-	1	511	1974
70	Mitra, A. K.	-	1	-	-	-	-	1	512	1976
71	Shamala, N.	-	1	-	-	-	-	1	513	1976
72	Reddy, A. H.	-	1	-	-	-	-	1	514	1976
73	Thanaraj, T. A.	-	9	2	1	1	-	13	527	1980-1987
74	Johnson, R. E. C.	-	-	-	1	-	-	2	529	1980-1981
75	Kulkarni, S. H.	-	2	-	-	1	-	3	532	1980-1981
76	Harishankar, R.	-	-	-	1	-	-	1	533	1981
77	Abdi, I. A.	-	-	-	-	1	-	1	534	1981
78	Rajan, S. S.	-	-	-	1	-	-	1	535	1983
79	Varughese, K. I.	-	-	-	1	-	-	1	536	1983
80	Krishnan, V.	-	2	-	-	-	-	2	538	1985
81	Upadhyaya, Ravi.	-	5	1	-	-	-	6	544	1988
82	Ramani, K.	-	-	-	1	-	-	1	545	1988

some papers the first author would be seen either as second and third author. This has been very much the case of as shown in Table 3. Prof. Ramachandran is the first and primary author in 271 papers, second author in 22 papers, third and fourth author each in three papers, fifth author in only one paper and sixth author in four papers.

Table 3. Prof. Ramachandran's authorship status.

No. of Papers	Position of Author							Total
	1st	2nd	3rd	4th	5th	6th	7th	
Single	147	-	-	-	-	-	-	147
2-Authored	85	18	-	-	-	-	-	103
3-Authored	33	3	3	-	-	-	-	39
4-Authored	5	-	-	3	-	-	-	8
5-Authored	1	-	-	-	1	-	-	2
6-Authored	-	1	-	-	-	1	-	2
7-Authored	-	-	-	-	-	3	-	3
Total	271	22	3	3	1	4	-	304

According to above Table Ramachandran is the first author in 271 papers. In 33 collaborative papers he is the secondary author. Collaborators who are the first authors in these 33 collaborative papers are listed in Table 4. R. Srinivasan and S. Parthasarathy each found to be first authors in four papers, J. T. Edsall in three papers, R. Chidambaram, G. Kartha in two papers each. The remaining authors are the first authors in one paper each.

Table 4. First authors in the collaborative papers where Ramachandran is the secondary author

Collaborating Author	Name of Collaborator with No. of Papers	Total
Two-Authored	R. Srinivasan (3), S. Parthasarathy (2), V. Ambrithalingam (1), M. Bansal (1), R. Chidambaram (1), P.B. Hirsch (1), G.Kartha (1), R. Parthasarathy (1), C.Ramakrishnan (1), S. Raman (1), S.Ramaseshan (1), K.P. Sarathy (1), V. Sasisekharan (1), K. Vedam (1), C. M. Venkatachalam (1)	18
Three-Authored	S. Parthasarathy (2), R. Chidambaram (1), A. R. Kalyanaraman (1), G. Krishnan (1), R. Srinivasan (1)	6
Four-Authored	R. Chandrasekharan (2) V. S. R. Rao (1)	3
Five-Authored	J. Dow (1)	1
Six-Authored	R. Balasubramaniam (1), G. Kartha (1)	2
Seven-Authored	J. T. Edsall (3)	3

Authorship status among core collaborators is plotted in Table 5. In this group Prof. G. N. Ramachandran published 52 papers with the core collaborators, out of 52 papers he is the first author in 39 papers, second author in seven papers, third author in only one paper, fourth author in three papers and sixth author in only one paper.

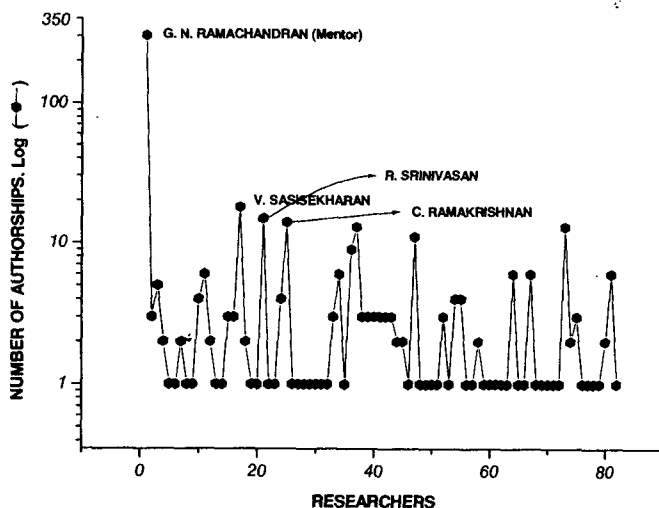


Figure 2. Publication productivity of the research group of Prof. G. N. Ramachandran in chronological order

Authorship status in collaborative publications

For any given researcher the authorship status changes from paper to paper. It has been noticed that in

Table 5. Authorship status of the core collaborators.

Core	No of Core Collaborative Papers & Status of Core Authors																Total
	2-Auts		3-Auts			4Auts				5-Auths					6-Auths		
	I	II	I	II	III	I	II	III	IV	I	II	III	IV	V	II	VI	
G.N.Ramachandran	20	5	15	2	1	4	-	-	3	-	-	-	-	-	1	52	
V.Sasisekharan	1	9	-	3	3	-	1	-	1	-	-	-	-	-	-	18	
R.Srinivasan	3	5	1	3	2	-	-	-	-	-	-	-	1	-	-	15	
C.Ramakrishnan	1	2	-	4	4	-	-	2	1	-	-	-	-	-	-	14	
A.V.Laxminarayana	-	4	-	2	1	-	3	1	1	-	-	-	-	-	1	13	

Out of 18 papers, Sasisekharan has collaborated only one paper as first author, 13 papers as second author, third author in three papers and fourth author in only one paper. R. Srinivasan appeared as first author in four papers, second author in eight papers, third author in two papers and fourth author in only one paper. C. Ramakrishnan has collaborated only one paper as first author with Ramachandran, second and third author in six papers and fourth author in only one paper. A. V. Laxminarayanan never appeared as first author, he is the second author in 10 papers, third author in two papers and fourth author in only one paper.

The quinquennial distribution of collaborating authors is given in Table 6. Thirteen collaborators were associated with Prof. Ramachandran during 1962-1966, followed by twenty four during 1967-1971, eighteen during 1972-1976, twelve during 1957-1961. In other quinquennial periods the collaboration authors were less than twelve.

Table 6. Quinquennial distribution of collaborating authors

Period	Authors	Total
1942-1946	G.N.R., V. Chandrasekharan	2
1947-1951	G.N.R., V. Chandrasekharan, W.A. Wooster, A.Lang, P.B.Hirsch, A.	8
1952-1956	G.N.R., Y.T.Thatachari, S. Ramaseshan, G. Kartha, G.K. Ambady, V.Amirthalingam, G.Krishnan, M.S.Santhanam, S.Raman, V.Sasisekharan	11
1957-1961	G.N.R., Y.T.Thatachari, S.	12
1962-1966	Ramaseshan, G. Kartha, M.S.Santhanam, S.Raman, V.Sasisekharan, K.S. Chandrasekharan, M.A.Lonappan, E.V.Krishnamurthy, R.Srinivasan, S.Vembu.	31
1967-1971	G.N.R., Y.T.Thatachari, G. Kartha, S.Raman, V.Sasisekharan, K.S. Chandrasekharan, R.Srinivasan, M.E.Dweltz, R.Parthasarathy, C.Ramakrishnan, S.Venkataraman, R.R.Iyer, H.B.Bhat, P.M.Nair, V.K.M.Rahavan, K.Venkataraman, M.Mallikarjun, R.Sarma, S.Parthasarathy, E.Subramaniam, C.M.Venkatachalam, A.M.Laxminarayana, J.T.Edsall, P.J.Flory, J.C.Kandrew, A.M. Liquori, G.Nemathy, H.A. Hcheraga, S.K.Mazumdar, K.Venkatesan, S.Krimm	24

V.S.R.Rao, P.R.Sundararajan,
B.B.Doyle, E.R.Blout, K.P.
Sarathy,A.R.Kalyanaraman,
R.Balasubramaniam, R.Chidambaram,
J.Dow, L.H.Jensen, G.Tgoni, K.Kopple,
M.N.Sabesan.

1972-1976	G.N.R., V.Sasisekharan, C. Ramakrishnan, A.M. Laxminarayanan, R. Chandrasekharan, K.P.Sarathy, R. Ramani, G.Ramachandran, S.G. Tagara, M.Bansal, R.S. Bhatnagar, P.Mohankrishanan, A.S.Kolaskar, U.V.Pandya, R.Narayan, A.K.Mitra, N.Shamala, A.H.Reddy.	18
1977-1981	G.N.R., T.A.Thanaraj, R.E.C. Johnson, S.H.Kulkarni, R. Harishankar, I.A.Abd, M.Bansal.	7
1982-1986	G.N.R., T.A.Thanaraj, S.S.Rajan, K.I.Varughese, V.Krishanan.	5
1987-1990	G.N.R., T.A.Thanaraj, Ravi Upadhyaya, K.Ramani	4

Channels of communication

Among 304 scientific papers, a total of 179 papers were research papers published in 44 different channels of communication. Channel-wise scattering of publications by him is provided in Table 7 and Figure 3. Top ranking journals with number of publications are: Proceedings of the Indian Academy of Sciences - A (48), Acta Crystallographica (21), Current Science (18), Nature (13), Biopolymers (12), Biochem Biophys Acta (8), and Biophys Acta (5). Sixty nine percent of his research papers were published in these top ranking seven journals. His published papers in the journal Nature had very high impact factor (27.955), with a total of thirteen articles (see Figure 3).

Table 7. Ranking of the channels of communication used by Prof. G. N. Ramachandran.

Rank	Title	No of papers	CNP	Fpy-LPY	Impact Factor
1	Proc. Indian Academy of sciences	48	48	1942-76	
2	Acta Crystallographica	21	69	1948-90	
3	Current Science	18	87	1944-86	
4	Nature	13	100	1945-63	
5	Biopolymers	12	112	1965-75	
6	Biochemistry, Biophysics, Acta	8	120	1965-74	

7	Biophysics, Acta	5	125	1962-70
8	Journal of Scientific and Industrial research	4	129	1960-70
8	Journal of Pure and Applied Physics	4	133	1963-71
8	Journal of Molecular Biology	4	137	1963-76
9	8 periodicals with 2 paper	16	153	
	26 periodicals with one paper	26	179	
	Book chapters and conference proceedings	35	214	
	Books, Edited Volumes, Monographs, and Reviews	13	227	
	Mathematical reports	77	304	

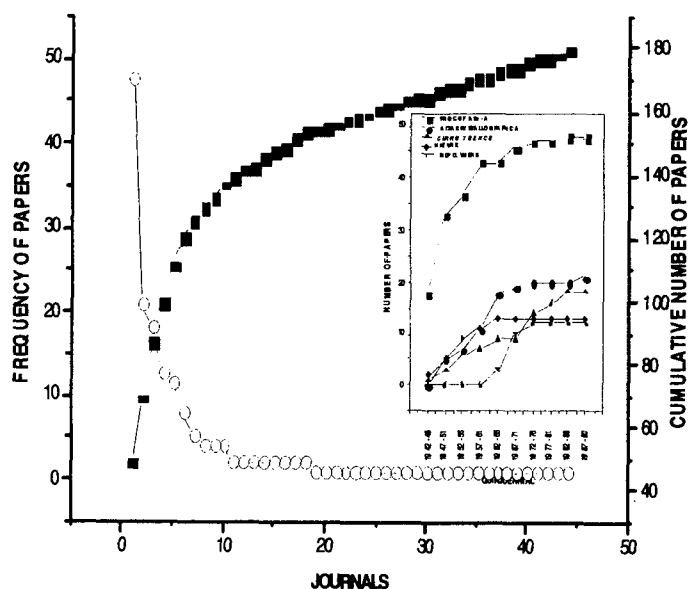


Figure 3. Bradford-Zipf bibliograph for G. N. Ramachandran and inset publications growth in seven core journals.

Bradford Distribution

Bradford's law is one of several statistical expressions that try to describe the workings of science by mathematical means⁶. It describes how the literature on a particular subject is scattered or distributed in various journals. If journals are ranked by the number of articles they contain on a given topic they can be divided into a central nucleus of the most important journal and a series of zones each containing the same number of articles as the nucleus (but each containing many more journals)⁷. In addition, ZIPF's Law⁸ describes the frequency distribution of words in a given text, with familiar words being used many times and many words being used only once. Bradford's and Zipf's laws have been shown to be

mathematically identical⁹ and so the distribution is often referred to as the Bradford-Zipf distribution.

Prof. Ramachandran had contributed 179 papers in reputed journals during the period of this study. To test whether or not his contributions follow Bradford distribution, each zone have around 60 papers. The first two journals account for 69 papers, and first three 87 papers. As 69 is closer to 60, hence 69 papers fall in the first zone. The remaining papers fall in the second and third zones. Zone-wise the papers and the journals can be divided as follows (Table 8).

Table 8. Distribution of papers and journals according to zones

Zones	1 st	2 nd	3 rd
Papers	69	51	59
Journals	2	4	38

We find from number of journals in the first two zones (vide table-8) that the Bradford Multiplier is $4/2=2$. According to this multiplier the number of periodicals in the third zone should be $2 \times 2 \times 2=8$ which is far from the actual number 38. The papers and the journals can also be distributed in the three different zones as follows.

Table 9. Distribution of papers and journals according to zones

Zones	1 st	2 nd	3 rd
Papers	69	60	50
Journals	2	6	36

In this case Bradford Multiplier is 3. According to this multiplier the number of journals in the third zone should be 18. In reality, it is 36. In both the cases we find that the number of journals in the third zone much beyond the actual number. Hence, the data does not strictly follow Bradford law. In any case, in small data sets Bradford distribution is not usually observed.

CONCLUSION

The present Scientometrics portrait study of Prof. Ramachandran's collected works undoubtedly proves the usefulness of his work to the fields of crystallography and molecular biophysics. Prof. Ramachandran has left behind a rich scientific legacy. The large amount of papers

written in his fields along with a large number of collaborators and his achievements gives inspiration for the generations to come in the field of interest throughout the world. He established a remarkable scientific tradition that thrives in the world, in India and in the two research schools he founded¹⁰. Ramachandran was undoubtedly one of the most outstanding scientists of post-Independence India and truly¹¹ a jewel in the crown of India's science.

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