

# Research Activities in Biochemistry, Genetics and Molecular Biology during 1998-2007 in India: A Scientometric Analysis

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## ABSTRACT

This study attempts to analyse the research profile of biochemistry, genetics and molecular biology research in India during 1998-2007, country's performance based on its research output, its publication share and rank in global context, and annual publication growth rate. It also analyses the share of international collaborative papers in India's research output, the characteristics of research output of major Indian institutions, authors, and highly-cited papers. The patterns of research communication by Indian scientists in most productive journals in this discipline have also been evaluated.

**Keywords:** Scientometrics, biochemistry, genetics, molecular biology

## 1. INTRODUCTION

The overlapping disciplines of biochemistry, genetics, and molecular biology placed between science and medicine developed rapidly in the early 20th century. These disciplines occupy a central position in modern biological research. There has never been a hard line between these disciplines in terms of content and technique. Researchers in biochemistry not only use specific techniques native to biochemistry, but combine techniques and ideas from genetics and molecular biology. Similarly, the researchers in molecular biology not only use specific techniques native to molecular biology, but combine techniques and ideas from genetics and biochemistry. Therefore, there is no defined line between these disciplines.

Biochemistry, soul of life sciences, has a versatile scope in the field of agriculture, pharmaceutical, nutritional, and medical sciences. It is the chemistry of life. It encompasses all aspects of biology, from molecules to cells, to organisms, to medicine, and to ecology. It interfaces with biology and chemistry and is concerned with the chemical processes that take place within living cells. Modern biochemistry, developed out of and largely came to replace what in the 19th and early 20th centuries was called physiological chemistry, and

began to emerge as an independent discipline from its medical origins. Thus, biochemistry as such is largely, though not exclusively, a 20th century discipline. The understanding of biochemistry has not only laid down the foundation for biotechnology but also the newer specialties like genetics. Molecular biology, agricultural biochemistry, biochemical pharmacology, immunology, etc. are also emerging from this parent subject.

Molecular biology is the study of biology at molecular level. It chiefly concerns itself with understanding the interactions between the various systems of a cell, including the interaction between DNA, RNA, and protein biosynthesis. The development of molecular biology is also the interaction of two disciplines, i.e., biochemistry and genetics which made considerable progress in the course of the first 30 years of the 20th century. The late 1950s to the early 1970s was a period of intense research and institutional expansion for molecular biology, which had only recently, became a somewhat coherent discipline.

Genetics is another discipline of biology, which was developed at the beginning of the 20th century. Genetics is the study of the effect of genetic differences of organisms. It is the scientific study of information in living organisms, how it is encoded within the cell, and how it is

transmitted from one generation to the next. Thus, genetics is essentially an understanding of fundamental biological processes such as evolution. It is a rapidly expanding applied field with new applications being discovered daily.

## 2 REVIEW OF LITERATURE

Tianwei He<sup>1</sup>, *et al.*, studied the research activities of China in biochemistry and molecular biology, during 1999-2002 in national and global context based on Science Citation Index expanded. Patra and Chand<sup>2</sup> analysed Indian biotechnology research by analysing its research profile, active authors, institutions and state-wise distributions of Indian biotechnology research output. Molatudi and Pouris<sup>3</sup> made a bibliometric analysis of South African microbiology, molecular biology, and genetics research, during 1980-2000 based on ISI database.

## 3. OBJECTIVES

The main objective of this study is to analyse the research performance of India in biochemistry, genetics, and molecular biology in national and global context during 1998-2007. In particular, the study focuses on the following objectives:

- (i) To study the research output, publication share, rank, and growth rate of India's publication productivity and 30 most productive countries of the world.
- (ii) To study the patterns of research collaboration.
- (iii) To study the publication productivity and impact of leading institutions of India.
- (iv) To study the characteristics of prolific authors and highly cited papers.
- (v) To study the patterns of research communication in most productive Indian and foreign journals.

## 4. METHODOLOGY AND SOURCE OF DATA

For this study, the data has been retrieved from the *Scopus* database, which is the single largest multidisciplinary bibliographical database in the world. In data in biochemistry, genetics, and molecular biology published during 1999-2008, India was compared with the research output of 30 most productive countries of the world. Three-year citations window was used for counting the citations received per paper and to assess the impact of leading Indian institutions and most productive authors. Impact factor 2006 has been used to examine the impact of various national and international journals in which Indian research communication has been published.

## 5. ANALYSIS

### 5.1 Research Output, Publication Share, and Growth Rate of Research in India in Global context

The Indian research output, its growth rate, publication share, and rank of India and top 30 countries in biochemistry, genetics and molecular biology during 1998-2007 have been analysed and presented in Tables 1 and 2. Among these top 30 countries USA published highest paper with 31.86 per cent share in the cumulative publication productivity of the world. Japan come at the 2nd place with 9.19 per cent publications share, followed by Germany (7.44 per cent), France (5.43 per cent), China (5.04 per cent), Italy (4.34 per cent), Canada (4.04 per cent).

India's place in this list was 10th with publication output of 45,712 papers and global publication share of 2.37 per cent in the cumulative publication output. India's global publications share also increased from 1.77 per cent to 3.07 per cent and so also the global publication rank from 14th in 1998 to 9th in 2007. India's annual publication growth rate was 11.50 per cent during 1998-2007, which rose to 16.96 per cent during 2003-2007 (Table 2).

It was also observed that publication productivity of most of the developed countries decreased in global context. The countries, which showed decrease in their global output share from 1998 to 2007, were USA, Japan, Germany, France, Netherlands, UK, Russia, Sweden, Switzerland and Belgium. In contrast, only few developed countries such as Italy, Canada, Spain, Australia, Poland, Denmark, Austria, Greece, Hong Kong, and Norway showed marginal increase (between 0.04 per cent to 0.72 per cent) in their global share during the same period (Table 2).

As against developed countries, most developing countries among 30 most productive countries showed increase in their global output share (between 0.15 per cent to 7.47 per cent) from 1998 to 2007. China had substantially improved its global publication share and publication rank from 12th in 1998 to 2nd in 2007. Similarly, India also improved its global publication rank from 14th in 1998 to 9th in 2007 (Table 2). The average annual publication growth rate of developed countries ranged between 0 per cent to 11 per cent, as compared to the developing countries which ranged between 3 per cent to 25 per cent during 1998-2007.

### 5.2 Status of India's International Collaboration

During 1998-2007, it was found that the share of international collaborative papers with India to its

**Table 1. Publication productivity and world share of India and most productive countries in Biochemistry, Genetics and Molecular Biology during 1998-2007**

Country	Total Papers			per cent Share of Papers			Country	Total Papers			per cent Share of Papers		
	1998	2007	98-07	1998	2007	98-07		1998	2007	98-07	1998	2007	98-07
USA	59507	72257	615,331	35.00	29.02	31.86	Switzerland	2981	4242	33532	1.75	1.70	1.74
Japan	17264	19261	177491	10.16	7.74	9.19	Brazil	1666	4297	26734	0.98	1.73	1.38
Germany	12830	17968	143659	7.55	7.22	7.44	Poland	1577	3426	24525	0.93	1.38	1.27
France	10296	12331	104799	6.06	4.95	5.43	Israel	2195	2912	24216	1.29	1.17	1.25
China	3519	23764	97319	2.07	9.54	5.04	Belgium	2161	3033	23939	1.27	1.22	1.24
Italy	6986	11112	83772	4.11	4.46	4.34	Columbia	2014	3324	23000	1.18	1.33	1.19
Canada	6906	10523	78005	4.06	4.23	4.04	Denmark	1763	2692	20703	1.04	1.08	1.07
Spain	4165	7884	55506	2.45	3.17	2.87	Taiwan	1244	2998	18591	0.73	1.20	0.96
Australia	3813	6196	46017	2.24	2.49	2.38	Austria	1371	2386	16981	0.81	0.96	0.88
India	3002	7653	45712	1.77	3.07	2.37	Finland	1381	2018	16234	0.81	0.81	0.84
Netherlands	4032	5772	44669	2.37	2.32	2.31	Turkey	628	2468	14570	0.37	0.99	0.75
U.K	4240	5190	43108	2.49	2.08	2.23	Mexico	816	1788	11857	0.48	0.72	0.61
Russia	4029	3638	40381	2.37	1.46	2.09	Greece	714	1810	11817	0.42	0.73	0.61
South Korea	2091	6716	40019	1.23	2.70	2.07	Hong Kong	735	1555	11541	0.43	0.62	0.60
Sweden	3388	4380	36623	1.99	1.76	1.90	Norway	917	1529	10642	0.54	0.61	0.55
World	169996	248992	1931282										

**Table 2. Annual publication growth rate of most productive countries in Biochemistry, Genetics, and Molecular Biology during 1998-2007**

Country	Growth rate in per cent		Country	Growth rate in per cent	
	1998-2007	2003-2007		1998-2007	2003-2007
World	4.44	7.77	Switzerland	4.41	9.54
USA	2.29	5.22	Brazil	11.45	13.5
Japan	1.30	3.16	Poland	9.38	12.12
Germany	4.05	8.17	Israel	3.40	6.58
France	2.28	6.45	Belgium	4.11	8.27
China	24.81	36.97	Columbia	6.20	12.90
Italy	5.56	9.45	Denmark	5.05	9.30
Canada	5.06	10.16	Taiwan	10.69	15.68
Spain	7.70	12.48	Austria	6.77	11.82
Australia	5.77	10.41	Finland	4.47	7.23
India	11.5	16.96	Turkey	17.12	16.72
Netherlands	4.36	9.00	Mexico	9.39	12.99
UK	2.58	7.37	Greece	11.36	15.16
Russia	-0.47	0.26	Hong Kong	9.67	13.22
South Korea	14.76	20.38	Norway	6.45	13.91
Sweden	3.00	5.86			

cumulative publication output was 17.20 per cent in biochemistry, genetics, and molecular biology research. India witnessed rise in their share of international collaborative papers from 16.18 per cent during 1998-2000 to 18.38 per cent during 2005-2007 (Table 3).

Table 3 shows that 21 countries have published more than 100 collaborative papers with India during this period.

Of these 21 countries, 14 belong to the developed world and seven to developing world. USA was the largest collaborative partner with 43.55 per cent publications share in India's cumulative international collaborative papers output during 1998-2007, followed by Germany (with 13.33 per cent), UK (with 12.98 per cent), Japan (8.01 per cent), France (5.95 per cent), Canada (4.39 per cent), Italy (3.52 per cent share) and so on. Among

developing countries, Malaysia contributed the highest share (4.64 per cent) with India, followed by South Korea (2.61 per cent), China (2.11 per cent), Taiwan (1.93 per cent), Israel (1.69 per cent), Singapore (1.50 per cent), and Columbia (1.30 per cent) (Table 4) of collaborative papers

### 5.3 Institutional Profile

Table 5 shows the 20 Indian institutions identified as high productive (ones publishing more than 500 papers) in the country output in this field during 1998-2007. Of these 20 institutions, eight were of national importance, six were universities, and six were research institutions.

These 20 institutions together contributed 40.91 per cent in the total publication productivity of India during 1998-2007; rising from 14.15 per cent in 1998-2002 to 26.76 per cent in 2003-2007. The cumulative publication output of these 20 institutions constitutes 18,702 papers with an average output of 935.1 papers per institution. Only six institutions, namely, Indian Institute of Science, Bangalore (2433 papers), University of Delhi, Delhi (1989 papers); AIIMS, Delhi (1291 papers); Indian Institute of Chemical Technology, Hyderabad (1239 papers); University of Madras, Chennai (1217 papers); University of Hyderabad, Hyderabad (977 papers) have contributed papers above the average productivity per institution.

**Table 3. Share of international collaborative papers in total publication output of India during 1998-2007**

Country	Total papers			Per cent share of papers			Country	Total papers			Per cent share of papers		
	1998	2007	98-07	1998	2007	98-07		1998	2007	98-07	1998	2007	98-07
USA	59507	72257	615,331	35.00	29.02	31.86	Switzerland	2981	4242	33532	1.75	1.70	1.74
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Russia	4029	3638	40381	2.37	1.46	2.09	Greece	714	1810	11817	0.42	0.73	0.61
S. Korea	2091	6716	40019	1.23	2.70	2.07	Hong Kong	735	1555	11541	0.43	0.62	0.60
Sweden	3388	4380	36623	1.99	1.76	1.90	Norway	917	1529	10642	0.54	0.61	0.55
World	169996	248992	1931282										

**Table 4. Country-wise share total international collaborative papers (TICP) of India during 1998-2007**

Country	TICP	Per cent share of TICP	Country	TICP	Per cent share of TICP
USA	3424	43.55	Spain	190	2.42
Germany	1048	13.33	China	166	2.11
UK	1021	12.98	Taiwan	152	1.93
Japan	630	8.01	Netherlands	150	1.91
France	468	5.95	Sweden	142	1.81
Malaysia	365	4.64	Israel	133	1.69
Canada	345	4.39	Singapore	118	1.5
Italy	277	3.52	Belgium	117	1.49
Australia	219	2.79	Denmark	115	1.46
S. Korea	205	2.61	Columbia	102	1.30
Switzerland	205	2.61			

**Table 5. Output, growth, and impact of top institutions of India in biochemistry, genetics, and molecular biology during 1998-2007**

S.No.	Institution	Total papers (TP)				TC	ACPP
		1998-07	1998-02	2003-07	Growth rate from 98-02 to 03-07		
1.	Indian Institute of Science, Bangalore	2433	889	1544	73.68	8885	3.65
2.	University of Delhi, Delhi	1989	733	1256	71.35	6373	3.20
3.	AIIMS, Delhi	1291	458	833	81.88	3854	2.99
4.	Indian Institute of Chemical Technology Hyderabad	1239	336	903	168.75	5932	4.79
5.	University of Madras, Chennai	1217	417	800	91.85	2846	2.34
6.	University of Hyderabad, Hyderabad	977	388	589	51.80	2949	3.02
7.	Indian Institute of Technology, Delhi	846	250	596	138.4	2686	3.17
8.	National Chemical Laboratory, Pune	841	375	466	24.27	3395	4.04
9.	Indian Institute of Technology, Mumbai	820	238	582	144.54	2849	3.47
10.	Banaras Hindu University, Varanasi	816	357	459	28.57	1535	1.88
11.	Central Drug Research Institute, Lucknow	768	240	528	120.00	2663	3.47
12.	Indian Institute of Technology, Chennai	721	229	492	114.85	1303	1.81
13.	Bhabha Atomic Research Centre, Mumbai	698	270	428	58.52	1876	2.69
14.	Jadavpur University, Kolkata	664	231	433	87.45	1982	2.98
15.	Centre for Cellular & Molecular Biology Hyderabad	631	225	406	80.44	3201	5.07
16.	Indian Institute of Chemical Biology, Kolkata	577	215	362	68.37	2092	3.63
17.	University of Mysore, Mysore	575	104	471	352.88	1096	1.91
18.	Indian Institute of Technology, Kanpur	554	158	396	150.63	2093	3.78
19.	Indian Institute of Technology, Kharagpur	525	140	385	175.00	1322	2.52
20.	Postgraduate Institute of Medical Education & Research (PGIMER), Chandigarh	520	215	305	41.86	1098	2.11

TP = Total Papers; TC = Total Citations; ACPP = Average Citations Per Paper

The average citation per paper (ACPP) received by total papers of these 20 most productive Indian institutions in Biochemistry, Genetics and Molecular Biology was 3.21 during 1998-2007. Only eight institutions have ACPP higher than the group average. These institutions are: Centre for Cellular & Molecular Biology, Hyderabad with 5.07 citations per paper, followed by Indian Institute of Chemical Technology, Hyderabad (4.79); National Chemical Laboratory, Pune (4.04); Indian Institute of Technology, Kanpur (3.78); Indian Institute of Science, Bangalore (3.65); Indian Institute of Chemical Biology, Kolkata (3.63); Central Drug Research Institute, Lucknow (3.47); and Indian Institute of Technology, Mumbai (3.47).

The average growth rate of these 20 institutions from 1998-2002 and 2003-2007 was 89.15 per cent. Nine institutions achieved higher annual average growth rate than the average growth of these 20 institutions. The University of Mysore, Mysore showed the highest growth rate of 352.88 per cent, followed by Indian Institute of Technology, Kharagpur (175 per cent); Indian Institute of Chemical Technology, Hyderabad (168.75 per cent); Indian Institute of Technology, Kanpur (150.63 per cent); Indian Institute of Technology, Mumbai (144.54 per cent);

Indian Institute of Technology, New Delhi (138.4 per cent); Central Drug Research Institute, Lucknow (120 per cent); Indian Institute of Technology, Chennai (114.85 per cent); and University of Madras, Chennai (91.85 per cent).

Table 6 shows that the average share of international collaborative papers of these 20 institutions was 17.83 per cent during 1998-2007. Ten institutions showed higher share of international collaborative papers than the average share of the 20 institutions. These institutions were: University of Mysore with international collaborative share of 36.70 per cent, followed by Jadavpur University, Kolkata (26.51 per cent); University of Madras, Chennai (25.88 per cent); Centre for Cellular & Molecular Biology, Hyderabad (23.77 per cent); Indian Institute of Technology, Mumbai (21.83 per cent); Indian Institute of Chemical Biology, Kolkata (21.32 per cent); University of Delhi (19.81 per cent); Indian Institute of Technology, Kharagpur (18.86 per cent); Indian Institute of Science, Bangalore (17.92 per cent); and Indian Institute of Technology, Kanpur (17.87 per cent) (Table 6).

The average h-index value of these 20 institutions was 30.15. Only nine institutions have scored higher h-index value than the group average of these institutions.

**Table 6. Output, international collaborative papers share and h-index of top institutions of India in Biochemistry, Genetics, and Molecular Biology, 1998-2007**

S.No.	Name of Institution	TP	TICP	Per cent share of TICP	h-index
1.	Indian Institute of Science, Bangalore	2433	436	17.92	45
2.	University of Delhi, Delhi	1989	394	19.81	41
3.	University of Madras, Chennai	1217	315	25.88	27
4.	AIIMS, Delhi	1291	215	16.65	34
5.	University of Mysore, Mysore	575	211	36.70	17
6.	Indian Institute of Technology, Mumbai	820	179	21.83	32
7.	Jadavpur University, Kolkata	664	176	26.51	27
8.	University of Hyderabad, Hyderabad	977	166	16.99	35
9.	Centre for Cellular and Molecular Biology, Hyderabad	631	150	23.77	36
10.	Banaras Hindu University, Varanasi	816	137	16.79	25
11.	Indian Institute of Chemical Biology, Kolkata	577	123	21.32	29
12.	Indian Institute of Technology, Delhi	846	119	14.06	31
13.	Indian Institute of Technology, Chennai	721	113	15.67	25
14.	Bhabha Atomic Research Centre, Mumbai	698	100	14.33	27
15.	National Chemical Laboratory, Pune	841	99	11.77	36
16.	Indian Institute of Technology, Kanpur	554	99	17.87	29
17.	Indian Institute of Technology, Kharagpur	525	99	18.86	22
18.	Central Drug Research Institute, Lucknow	768	80	10.42	28
19.	Indian Institute of Chemical Technology, Hyderabad	1239	80	6.46	39
20.	Post Graduate Institute of Medical Education and Research (PGIMER), Chandigarh	520	43	8.27	18

TP = Total Papers; TICP = Total International Collaborative Papers

These institutions were: Indian Institute of Science, Bangalore with h-index of 45, followed by University of Delhi (41), Indian Institute of Chemical Technology, Hyderabad (39); National Chemical Laboratory, Pune, Centre for Cellular & Molecular Biology, Hyderabad (36); University of Hyderabad (35); All India Institute of Medical Sciences, Delhi (34); Indian Institute of Technology, Mumbai (32); and Indian Institute of Technology, Delhi (31) (Table 6).

#### 5.4 Highly Productive Authors

Table 7 shows the most productive Indian authors in the field of biochemistry, genetics and molecular biology during 1998-2007. Of the 20 most productive authors, three are affiliated to institutes of national importance, eight to universities, one to engineering college, and eight to research laboratories. These authors together contributed 2,424 papers with an average of 121.2 papers per author during 1998-2007. Only six authors have contributed papers above the group average productivity. These were: HS Yathirajan with 231 papers, followed by JS Yadav (204 papers), KR Ravikumar (201 papers), D Velmurugan (188 papers), B Narayana (165 papers), and K Chinnakali (130 papers).

The average citation per paper received by these authors was 6.85. Nine authors scored average citations per paper higher than the group average (6.85). A.K. Pandey scored highest average citations 15.70 per paper, followed by JS Yadav (14.55), BVS. Reddy (13.93), A Surolia (13.76), V Nair (13.6) and G Mehta (11.53).

The average h-index value of these 20 authors was 13.5. Nine authors have scored h-index value higher than the group average (13.5). The highest h-index value (27) was of JS Yadav, followed by A Surolia (22), V Nair (21), BVS Reddy (18), AK Pandey (16), MN Gupta (16), G Mehta (16), VS Parmar, (16) and M Nethaji (14).

#### 5.5 Highly Productive Journals

Table 8 shows the 15 foreign journals which together contributed 22.52 per cent of India's total publication output in Biochemistry, Genetics and Molecular Biology during 1998-2007. The publication output share of these 15 journals also showed rise from 5.94 per cent during 1998-2002 to 16.59 per cent during 2003-2007. Of these 15 journals, *Journal of Biological Chemistry* had scored the highest impact factor (IF) of 5.81. Six other journals have IF more than 2, and two journals have IF more than 1.

**Table 7. h-index of most productive authors of India in Biochemistry, Genetics and Molecular Biology during 1998-2007**

S. No	Name	Affiliation	TP	TC	ACPP	h-index
1.	Yathirajan, Hemmige S.	University of Mysore, Department of Studies in Chemistry Mysore	231	484	2.10	9
2.	Yadav, Jhillu Singh	Indian Institute of Chemical Technology, Organic Chemistry Division-I, Hyderabad	204	2968	14.55	27
3.	Ravikumar, Krishnan R.	Indian Institute of Chemical Technology, Laboratory of X-ray Crystallography, Hyderabad	201	353	1.76	7
4.	Velmurugan, Devadasan	University of Madras, Department of Crystallography and Biophysics, Chennai	188	522	2.78	10
5.	Narayana, Badiadka	Mangalore University India, Department of Studies in Chemistry, Mangalagangothri	165	398	2.41	9
6.	Chinnakali, Kandasamy	Anna University, Department of Physics, Chennai	130	481	3.7	12
7.	Surolia, Avadhesh	National Institute of Immunology India, New Delhi	120	1651	13.76	22
8.	Raghunathan, Raghavachary	University of Madras, Department of Organic Chemistry, Chennai	116	557	4.80	9
9.	Singh, Tej Pratap	All India Institute of Medical Sciences, Department of Biophysics, New Delhi	106	708	6.68	13
10.	Sarojini, Balladka Kunhanna	P. A. College of Engineering, Department of Chemistry, Mangalore	103	394	3.83	11
11.	Pandey, Ashok Kumar	Regional Research Laboratory, Biotechnology Division, Thiruvananthapuram	92	1444	15.70	16
12.	Nair, Vijay	Regional Research Laboratory, Organic Chemistry Division, Thiruvananthapuram	90	1224	13.6	21
13.	Gupta, Munishwar Nath	Indian Institute of Technology, Department of Chemistry, New Delhi	91	899	9.88	16
14.	Kumar, Ashok Narendra	Devi Ahilya University of Indore, School of Chemical Sciences, Indore	88	586	6.66	13
15.	Mehta, Goverdahan	Indian Institute of Science, Department of Organic Chemistry, Bangalore	87	1003	11.53	16
16.	Reddy, B. V S	Indian Institute of Chemical Technology, Division of Organic Chemistry, Hyderabad	85	1184	13.93	18
17.	Nethaji, Munirathinam	Indian Institute of Science, Department of Inorganic and Physical Chemistry, Bangalore	84	613	7.30	14
18.	Parmar, Virinder Singh	University of Delhi, Department of Chemistry, New Delhi	83	839	10.11	16
19.	Sridhar, Balasubramanian	Indian Institute of Chemical Technology, Laboratory of X-ray Crystallography, Hyderabad	80	128	1.6	5
20.	Natarajan, S.	Madurai Kamaraj University, School of Physics, Madurai	80	180	2.25	6

TP = Total Papers; TC = Total Citations; ACPP = Average Citations Per Paper

Similarly, the 15 Indian journals which together contributed 24.11 per cent in the cumulative publication productivity of India during 1998-2007 are shown in Table 9. Table 9 shows that their publication share rose from 9.38 per cent during 1998-2002 to 14.73 per cent during 2003-2007 in Biochemistry, Genetics and Molecular Biology. Of these 15 Indian journals *Indian Journal of Medical Research* has IF more than 1. Seven Indian journals have IF below 1.

## 5.6 Highly Cited Papers

The characteristics of highly cited papers of India in Biochemistry, Genetics and Molecular Biology were also evaluated (*Appendix 1*). Based on publication output of India in this area, 27 papers were identified as highly

cited. These papers received 230 or more citations during 1998-2007. Of these 27 papers, 18 appeared as articles, Seven appeared as reviews, and two as short surveys. These 27 papers together received 9,337 citations with an average of 345.81 citations per paper. Only eight papers had higher citations per paper than the group average. The authors of these papers are affiliated to 19 Indian institutions including four from National Centre for Biological Sciences, TIFR (Bangalore); three each from Indian Institute of Science (Bangalore) and Tata Institute of Fundamental Research (Mumbai), two each from Jawaharlal. Nehru Centre for Advance Science. Research (Bangalore), AIIMS (Delhi) and Institute of Bio informatics (Bangalore) and rest from other 13 institutions. All of these papers were published in 12 international journals with eight papers in *Nature*, seven in *Science*, two in

**Table 8. Foreign journals which published papers of India in biochemistry, genetics and molecular biology during 1998-2007**

S. No.	Journal Name	Total Papers			IF (2006)
		1998-2007	1998-2002	2003-2007	
1.	<i>Tetrahedron Letters</i>	1992	622	1370	2.509
2.	<i>Acta Crystallographica Section E Structure Reports Online</i>	1290	0	1290	0.567
3.	<i>Lecture Notes in Computer Science Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics</i>	1178	0	1178	N.A
4.	<i>Asian Journal of Microbiology Biotechnology and Environmental Sciences</i>	932	155	777	N.A
5.	<i>Tetrahedron</i>	772	299	473	2.817
6.	<i>Polyhedron</i>	516	187	329	1.843
7.	<i>Biochemical and Biophysical Research Communications</i>	498	196	302	2.855
8.	<i>Acta Crystallographica Section C Crystal Structure Communications</i>	476	325	151	00.896
9.	<i>World Journal of Microbiology and Biotechnology</i>	460	222	238	00.471
10.	<i>Molecular and Cellular Biochemistry</i>	428	140	288	1.862
11.	<i>Bioorganic and Medicinal Chemistry Letters</i>	408	78	330	2.538
12.	<i>Bioorganic and Medicinal Chemistry</i>	388	100	288	2.624
13.	<i>Journal of Biological Chemistry</i>	388	140	248	5.808
14.	<i>Process Biochemistry</i>	307	133	174	2.008
15.	<i>Acta Cytologica</i>	263	117	146	00.793

**Table 9. Productive Indian journals which published papers of India in biochemistry, genetics and molecular biology during 1998-2007**

S. No.	Journal	Total Papers			IF(2006)
		1998-2007	1998-2002	2003-2007	
1.	<i>Current Science</i>	5075	1663	3412	00.737
2.	<i>Indian Journal of Medical Research</i>	1002	354	648	01.224
3.	<i>Journal of Scientific and Industrial Research</i>	901	373	528	00.178
4.	<i>Indian Drugs</i>	798	690	108	N.A
5.	<i>Indian Journal of Physiology and Pharmacology</i>	649	380	269	N.A
6.	<i>Indian Journal of Biochemistry and Biophysics</i>	533	297	236	00.277
7.	<i>Indian Journal of Biotechnology</i>	444	36	408	N.A
8.	<i>Indian Journal of Clinical Biochemistry</i>	272	0	272	N.A
9.	<i>Defense Science Journal</i>	255	205	50	00.118
10.	<i>Indian Journal of Cancer</i>	253	123	130	N.A
11.	<i>Journal of Plant Biochemistry and Biotechnology</i>	242	109	133	00.316
12.	<i>Biosciences Biotechnology Research Asia</i>	238	0	238	N.A
13.	<i>Sadhana Academy Proceedings in Engineering Sciences</i>	136	1	135	00.165
14.	<i>Journal of Genetics</i>	126	58	68	00.528
15.	<i>Indian Journal of Agricultural Biochemistry</i>	99	0	99	N.A



*Tetrahedron*, two in *Circulation* and remaining eight papers in eight other journals.

## 6. CONCLUSION

India was 10th among the top 30 productive countries of the world in Biochemistry, Genetics, and Molecular Biology with publication output of 45,712 papers and 2.37 per cent global publication share during 1998-2007. India witnessed rise in global from 1.77 per cent in 1998 to 3.07 per cent in 2007. Correspondingly, India's world ranking improved from 14th in 1998 to 9th in 2007. India holds at 4th in global context in terms of annual average publication growth rate of 11.50 per cent during 1998-2007, rose to 16.96 per cent during 2003-2007.

The cumulative publication output of India was 17.20 per cent of international collaborative papers during 1998-2007. India has share of internationally collaborative papers from 16.81 per cent during 1998-2000 to 18.38 per cent during 2005-2007. Among the collaborative countries, USA and Malaysia were the major collaborators in the category of developed and developing countries, respectively.

The cumulative production share of 20 most productive institutions in India's total research output during 1998-2007 was 40.91 per cent with 18,702 papers, rising from 14.15 per cent in 1998-2002 to 26.76 per cent during 2003-2007. The average growth rate of these institutions from 1998-2002 to 2003-2007 was 89.15 per cent. The average citations per paper, average h-index and average share of international collaborative papers of

these institutions were 3.21 per cent, 30.15 per cent, and 17.83 per cent.

The 20 most prolific Indian authors together in Biochemistry, Genetics and Molecular Biology contributed 2,424 papers, with an average of 121.2 papers per author. These authors had an average of 6.85 citations per paper and average h-index of 13.5 per author.

The total publication output of top 20 productive foreign and Indian journals in Biochemistry, Genetics and Molecular Biology together was 22.52 per cent and 24.11 per cent share to the total publication output of India in this field during 1998-2007. The top 27 highly cited papers of India, published in 12 foreign journals received total 9,337 citations, with an average of 345.81 citations per paper.

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## Highly cited papers of India in Biochemistry, Genetics and Molecular Biology during 1998-2007

Authors	Title	Year	Source	# of citations	Authors with affiliations	Document type
Wang J., Neaton J.B., Schlom D.G., Waghmare U.V., Spaldin N.Aetal	Epitaxial BiFeO <sub>3</sub> multiferroic thin film heterostructures	2003	<i>Science</i>	717	Waghmare, U.V., J. Nehru Ctr. for Adv. Sci. Research, Jakkur, Bangalore S60 064, India;	Article
Varma R., Mayor S.	GPI-anchored proteins are organized in submicron domains at the cell surface	1998	<i>Nature</i>	621	Varma, R., Mayor, S. Natl. Centre for Biological Sciences, TIFR Centre, IISc Campus, Post Box 1234, Bangalore 560012, India;	Article
Bhalla U.S., Iyengar R.	Emergent properties of networks of biological signaling pathways	1999	<i>Science</i>	587	Bhalla, U.S., , Natl. Centre for Biological Sciences, Post Office Box 1234, Bangalore 560012, India;	Article
Saji N.H., Goswami B.N., Vinayachandran P.N., Yamagata T.	A dipole mode in the tropical Indian ocean	1999	<i>Nature</i>	550	Goswami, B.N., Ctr. for Atmosph. and Oceanic Sci., Indian Institute of Science, Bangalore 560 012, India;	Article
Kotha S., Lahiri K., Kashinath D.	Recent applications of the Suzuki-Miyaura cross-coupling reaction in organic synthesis	2002	<i>Tetrahedron</i>	547	Kotha, S., Lahiri, K., Kashinath, D. Department of Chemistry, Indian Institute of Technology-Bombay, Powai, Mumbai 400 076, India	Review
Norman M.R., Ding H., Randeria M., Campuzano J.C., et al.	Destruction of the Fermi surface in underdoped high-T(c) superconductors	1998	<i>Nature</i>	523	Randeria, M., Tata Inst. of Fundamental Research, Mumbai 400005, India;	Article
Yusuf S., Reddy S., Ounpuu S., Anand S.	Global burden of cardiovascular diseases. Part I: General considerations, the epidemiologic transition, risk factors, and impact of urbanization	2001	<i>Circulation</i>	427	Reddy, S., All India Institute of Medical Sciences, New Delhi, India	Article
Reddy K.S., Yusuf S.	Emerging epidemic of cardiovascular disease in developing countries	1998	<i>Circulation</i>	368	Reddy, K.S., Department of Cardiology, All India Inst. of Medical Sciences, New Delhi, India,	Review
Peng J., Richards D.E., Hartley N.M., Murphy G.P., Devos K.M., Flintham J.E., Beales J., Fish L.J., Worland A.J., Pelica F., Sudhakar D., Christou P., Snape J.W., Gale M.D., Harberd N.P.	'Green revolution' genes encode mutant gibberellin response modulators	1999	<i>Nature</i>	340	Sudhakar, D Rice Transformation Laboratory, Centre for Plant Molecular Biology, Tamil Nadu Agricultural University, Coimbatore-641 003, India;	Article
Rao M.B., Tanksale A.M., Ghatge M.S., Deshpande V.V.	Molecular and biotechnological aspects of microbial proteases	1998	<i>Microbiology and Molecular Biology Reviews</i>	338	Division of Biochemical Sciences, National Chemical Laboratory, Pune 411008, India	Review
Schwille P., Haupts U., Maiti S., Webb W.W.	Molecular dynamics in living cells observed by fluorescence correlation spectroscopy with one- and two-photon excitation	1999	<i>Biophysical Journal</i>	284	Maiti, S., Tata Inst. of Fundamental Research, Colaba, Mumbai 400 005, India;	Article

Gerard M., Chaubey A., Malhotra B.D.	Application of conducting polymers to biosensors	2002	<i>Biosensors and Bioelectronics</i>	271	Gerard, M., Chemistry Department, Allahabad Agricultural Institute Allahabad, India; Chaubey, A., Malhotra, B.D., Biomolecular Electronics and Conducting Polymer Research Group, National Physical Laboratory, Dr. K.S. Krishnan Marg, New Delhi 110 012, India;	Review
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Ramirez A.P., Hayashi A., Cava R.J., Siddharthan R., Shastry B.S.	Zero-point entropy in 'spin ice'	1999	<i>Nature</i>	268	Siddharthan, R., Shastry, B.S., Department of Physics, Indian Institute of Science, Bangalore	Article
Sastry S.	The relationship between fragility, configurational entropy and the potential energy landscape of glass-forming liquids	2001	<i>Nature</i>	264	Sastry, S., Jawaharlal Nehru Ctr. Adv. Sci. Res., Jakkur Campus, Bangalore 560064, India	Article
Pal-Bhadra M., Leibovitch B.A., Gandhi S.G., Rao M., Bhadra U., Birchler J.A., Elgin S.C.R.	Heterochromatic Silencing and HP1 Localization in <i>Drosophila</i> Are Dependent on the RNAi Machinery	2004	<i>Science</i>	259	Pal-Bhadra, M., Gandhi, S.G.; Rao, M., Bhadra, U., Funct. Genom./Gene Silencing Grp., Ctr. for Cell. and Molecular Biology, Hyderabad 500007, India;	Article
Banat I.M., Makkar R.S., Cameotra S.S.	Potential commercial applications of microbial surfactants	2000	<i>Applied Microbiology and Biotechnology</i>	259	Makkar, R.S., Cameotra, S.S., Inst. of Microbial Technol. (IMTECH), Sector 39-A, Chandigarh 160036, India,	Short Survey
Petit R.J., Aguinagalde I., De Beaulieu J.-L., Bittkau C., Mohanty A., Muller-Starck G., <i>et al.</i>	Glacial refugia: Hotspots but not melting pots of genetic diversity	2003	<i>Science</i>	256	Mohanty, A., Intl. Ctr. Genet. Eng./Biotechnol., Aruna Asaf Ali Marg, New Delhi-110067, India;	Article
Kumar K.K., Rajagopalan B., Cane M.A.	On the weakening relationship between the indian monsoon and ENSO	1999	<i>Science</i>	256	Kumar, K.K., Indian Inst. of Tropical Meteorology, Dr. Homi Bhabha Road, Pashan, Pune 411008, India;	Article
Jain N., Kumar A., Chauhan S., Chauhan S.M.S.	Chemical and biochemical transformations in ionic liquids	2005	<i>Tetrahedron</i>	255	Bioorganic Laboratory, Department of Chemistry, University of Delhi, Delhi, India	Review
Bhalla U.S., Ram P.T., Iyengar R.	MAP kinase phosphatase as a locus of flexibility in a mitogen-activated protein kinase signaling network	2002	<i>Science</i>	252	Bhalla, U.S., Ram, P.T., Iyengar, R., Natl. Center for Biological Sciences, Bangalore 560065, India	Article

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Sharma P., Varma R., Sarasij R.C., Ira, Gousset K., Krishnamoorthy G., Rao M., Mayor S.	Nanoscale Organization of Multiple GPI-Anchored Proteins in Living Cell Membranes	2004	<i>Cell</i>	242	Sharma, P., Varma, R, Mayor, S.Rao, M. Natl. Centre for Biological Science, UAS-GKVK Campus, GKVK PO, Bangalore 560 065, India; Sarasij, R.C., Raman Research Institute, CV Raman Avenue, Bangalore 560 080, India; Ira, Krishnamoorthy, G., Department of Chemical Sciences, Tata Inst. of Fundamental Research, Homi Bhabha Road, Mumbai 400005, India.	Article
Sastry P.S., Rao K.S.	Apoptosis and the nervous system	2000	<i>Journal of Neurochemistry</i>	242	Department of Biochemistry, School of Life Sciences, University of Hyderabad, India	Short survey
Rhodes D.R., Yu J., Shanker K., Deshpande N., etal.	ONCOMINE: A Cancer Microarray Database and Integrated Data-Mining Platform	2004	<i>Neoplasia</i>	234	Shanker, K., Deshpande, N., Institute of Bioinformatics, Bangalore, India;	Review
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Weng G., Bhalla U.S., lyengar R.	Complexity in biological signaling systems	1999	<i>Science</i>	231	Bhalla, U.S., Natl. Center for Biological Sciences, UAS-GKVK Campus, Bangalore 560065, India;	Review