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# Bibliometric tools applied to analytical articles: the example of gene transfer-related research

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## Abstract

**Purpose** – The objective of this study is to conduct a bibliometric indicator and to conduct an analysis of citations per publication of all horizontal gene transfer-related publications in the Science Citation Index (SCI). A systematic search was performed using the SCI for publications during the period 1991-2005.

**Design/methodology/approach** – The data were based on the online version of the Science Citation Index (SCI), Web of Science. Analyzed parameters included authorship, patterns of international collaboration, journal, language, document type, number of times cited, author, and KeyWords Plus.

**Findings** – The USA and Germany produced 57 percent of the total articles and 77 percent of the total times cited in three years after publication. In addition, a simulation model was applied to describe the relationship between the cumulative number of citations and the article life.

**Originality/value** – This is one of the first studies that uses analysis of citations per publication, defined as the ratio of the number of citations per publication in a certain period, to assess the impact relative to the entire field.

**Keywords** Serials, Genetics, Research results, Publishing

**Paper type** Research paper

## Introduction

Horizontal gene transfer (HGT), or lateral gene transfer (LGT), is the collective name for processes that permit the exchange of DNA among organisms of different species (Jain *et al.*, 2003). In the reproduction strategies of a replicon, vertical transfer of chromosome is the faithful way of increasing the genotype of a species, while horizontal transfer of transposon, plasmids or viruses provides the chance of creating a recombinant genotype by contributing to the genome of a neighbor recipient cell (Heinemann, 1998; Brown, 2003).

The earliest mention of HGT can be traced to 1905, when Merechowsky suggested that the eukaryotic mitochondria and chloroplast originated when bacteria invaded the eukaryotic cell and were subsequently incorporated by it (Syvanen and Kado, 1998). In the 1950s, upon the previous attempts of demonstrating recombination between diverse species of bacteria, Baron *et al.* (1959) and Miyake and Demerec (1959) reported that high frequency of recombination (Hfr) strains of *Escherichia coli* could transfer genetic information to certain mutant strains of *Salmonella typhimurium*. Ochiai *et al.*



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(1959) discovered infectious multiple-antibiotic resistant plasmids in pathogenic bacteria. Theoretical implications of HGT began to grow from the view of evolution in the 1970s (Went, 1971; Hartman, 1984). By the mid-1980s, numerous mechanisms for natural HGT were firmly established in the range from bacteria to metazoans (Ochman and Selander, 1984; Erwin and Valentine, 1984; Syvanen, 1984, 1987). However, the name “horizontal gene transfer” did not appear in the title, abstract or keywords of a publication until 1983, when *Aporpium* was reported as an example of horizontal gene-transfer (Setliff, 1983). In the succeeding research history, with the advance of molecular biology, more and more available scientific evidence has indicated that HGT is a natural process among wild-type organisms of prokaryotes (Penalva *et al.*, 1990; Di Giovanni *et al.*, 1996; Eisen, 2000; Koonin *et al.*, 2001) and eukaryotes (Penalva *et al.*, 1990; Rosewich and Kistler, 2000; Andersson, 2003). Now, under increasing pressure from human society, HGT is detected frequently, related to the occurrence of resistance to herbicides (Ka and Tiedje, 1994; de Liphay *et al.*, 2001) or antibiotics (Penalva *et al.*, 1990; Coffey *et al.*, 1995; Shoemaker *et al.*, 2001; Zolezzi *et al.*, 2004), and the catabolic pathways for the degradation of synthetic compounds (Herrick *et al.*, 1997; van der Meer *et al.*, 1998; Top *et al.*, 2002; Wilson and Metcalf, 2005).

In this study, the authors attempted to analyze bibliometrically the HGT-related literature published in journals listed in SCI from 1991 to 2005, in order to provide insights into the characteristics of the HGT literature and identify patterns, tendencies, or irregularities that may exist in the literature. An indicator, citations per publication, was also applied in this study. Furthermore, this will provide a comprehensive evaluation of current HGT research.

### Methodology

The data were based on the online version of the Science Citation Index (SCI), Web of Science. SCI is multidisciplinary database of the Institute for Scientific Information (ISI), Philadelphia, USA. One common way of conducting bibliometric research is to use the SCI database to trace the times each document has been cited (Hsieh *et al.*, 2004). In the 2005 edition of the *Journal Citation Reports* (JCR), 6,088 journals are listed in the SCI. “Horizontal-gene-transfer” or “lateral-gene-transfer” were used as keywords to search titles, abstracts, and keywords to identify HGT-related publications from 1991 to 2005. Articles originating from England, Scotland, Northern Ireland and Wales were re-categorized as being from the UK. Collaboration type was determined by the address of each author, where the term “single country” was assigned if the researchers’ addresses were from the same country. The term “international collaboration” was designated to those articles that were co-signed by researchers from different countries.

The information downloaded included names of authors, contact address, title, year of publication, keywords, times cited, subject categories of the journal, names of journals publishing the articles, and publisher information. The records were downloaded into spreadsheet software, and additional coding was performed manually for the number of authors, country of origin of the collaborators, and impact factors of the publishing journals. Impact factors were taken from the *Journal Citation Report* (JCR) published in 2005.

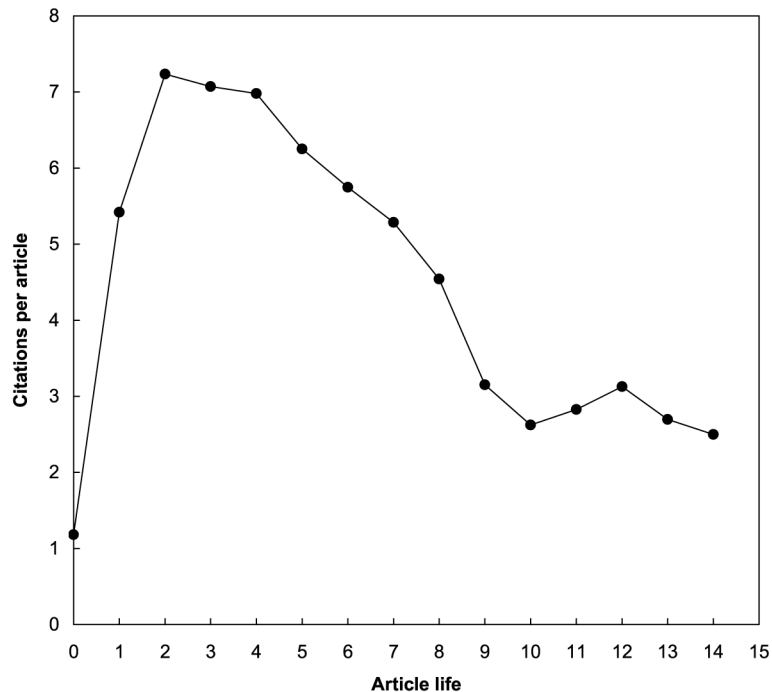
To assess the visibility of an article, the authors used the number of times it was cited as an indicator. The number of times cited for an article, however, is highly

correlated with the length of time since its publication. To adjust for that, a new variable was created (Chuang *et al.*, 2007). Figure 1 shows the relationship between the average number of times cited per paper and the number of years since the paper's publication for all HGT-related articles from 1991 to 2005. It shows that the frequency of being cited was highest in the second full year since publication, and began to decrease thereafter. To adjust for bias due to differences in the length of time since publication, a new variable, TC2 (times cited before year 2), instead of just times cited since publication, was used to assess the visibility of articles. A TC2 for the year 2003 would be the number of times being cited before 2006 for all articles published in 2003. Another variable CPP (citation per publication) for articles published in a particular year was calculated as TC2 divided by the number of articles published in that year. In some cases, the authors only discuss documents published in the period 1991-2003, since articles published after 2003 would not have TC2 and CPP values during the analyzing period, i.e. 1991-2005.

### Results and discussion

#### *Document type and language*

There were 1,549 HGT-related documents published from 1991 to 2005. The distribution of document types identified by ISI was analyzed as listed in Table I. For the period 1991-2003, journal article was the most frequent document type, 765 articles comprising 79 percent of total production with a CPP of 14, followed distantly by 173 reviews comprising 18 percent of total production with a CPP of 20. Editorial material, letters, meeting abstracts, corrections, reprints, bibliographies, news items, notes, and



**Figure 1.**  
Citations per article by  
article life for 1,208  
HGT-related articles from  
1991 to 2005

Document type	1991-2005 P	P	1991-2003 TC2	CPP
Article	1,208 (78)	765 (79)	10,823	14
Review	282 (18)	173 (18)	3,378	20
Editorial material	28 (1.8)	18 (1.8)	173	10
Letter	16 (1.0)	10 (1)	136	14
Meeting abstract	28 (0.39)	3 (0.31)	0	0
Correction	3 (0.19)	1 (0.10)	0	0
Reprint	2 (0.13)	2 (0.21)	25	13
Bibliography	1 (0.065)	0 (0)	0	0
News item	1 (0.065)	1 (0.10)	0	0
Note	1 (0.065)	1 (0.10)	13	13
Software review	1 (0.065)	0 (0)	0	0
Total	1,549	974	14,548	15

**Notes:** Figures in parentheses are percentages. P, number of papers; TC2, times cited before the second full year since publication; CPP, citation per publication

**Table I.**  
Document distributions  
from 1991 to 2005 with  
CPP from 1991 to 2003

software reviews showed lesser significance than articles and reviews. As journal articles represented the majority of document types that were also peer-reviewed within this field, a total of 1,208 relevant articles in the period 1991-2005 was identified and analyzed. The percentage of reviews related with HGT (18 percent) was notably high, however, implying that the HGT research is much comprehensive. The concept of HGT provides a penetrating insight into many significant phenomena of life, such as evolution, adaptation, genetic modification, recombination, antibiotic resistance, conjugation, transduction, and transformation.

The predominant language for all journal articles was English (99 percent); others were published in French, (four articles, 0.44 percent), German (two articles, 0.22 percent), and Chinese and Russian (one article, 0.11 percent), respectively. Garfield and Welljamsdorff (1992) reported that English is the main language of microbiology research, accounting for 90-95 percent of all SCI papers. In addition, it could be expected that English would be used more frequently because more journals listed in ISI were published in English.

#### *Chronological publication output*

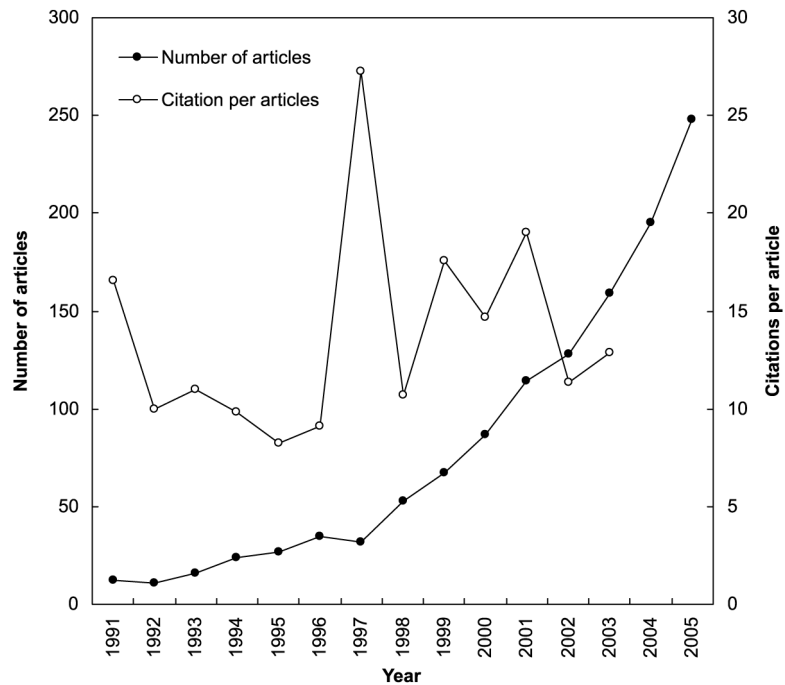
There were 1,208 HGT-related articles published from 1991 to 2005. Table II shows that the number increased significantly from 1991 (12 articles) to 1997 (32 articles). After 1997 there was been a large increase, reaching 195 articles in 2004 and 248 articles in 2005. Table II also shows TC2 and CPP during the period 1991-2003. Only 765 articles had CPP values. The average CPP was 14. The lowest CPP was found in 1995 at 8.2, while the highest CPP occurred in 1997 at 27. Figure 2 also shows that CPP has fluctuated over the years and a peak appeared in the year 1997. The reason for this is that Kunst *et al.* (1997) published "The complete genome sequence of the Gram-positive bacterium *Bacillus subtilis*" in *Nature*, with a TC2 of 499. This article analyzed the complete genetic information of a bacterial strain, *Bacillus subtilis*, the best-characterized member of the Gram-positive bacteria. In its genome, many genes are involved in the synthesis of secondary metabolites including antibiotics, and a few prophages or remnants of prophages are contained, indicating that bacteriophage

Year	No. of articles	TC2	CPP	ICA
1991	12	199	17	3 (25)
1992	11	110	10	4 (36)
1993	16	176	11	7 (44)
1994	24	236	10	3 (13)
1995	27	222	8	4 (15)
1996	35	320	9	8 (23)
1997	32	871	27	6 (19)
1998	53	566	11	13 (25)
1999	67	1,177	18	17 (25)
2000	87	1,277	15	22 (25)
2001	114	2,171	19	38 (33)
2002	128	1,454	11	37 (29)
2003	159	2,044	13	30 (19)
2004	195			60 (31)
2005	248			79 (32)
Total	1,208			331 (27)

**Table II.**

Article characteristics by year of publication

**Notes:** Figures in parentheses are percentages. TC2, times cited before the second full year since publication; CPP, citation per publication; ICA, international co-authorship



**Figure 2.**

Relationships among the number of articles, citation per articles, and year

infection has played an important evolutionary role in horizontal gene transfer. Since its publication, this article was cited 1,633 times up to 2005 by 49 countries. Later, increasing studies of genes and genomes have indicated that considerable horizontal transfer has occurred between different species, leading to the steep increase in the number of HGT-related articles published after 1997.

#### *International collaboration*

Of the 1,208 articles, 331 articles, or about 27 percent, had international co-authorship (ICA). The annual percentage of articles with ICA is listed in Table II. The percentage of ICA articles was highest in 1993 at 44 percent, followed by 1992 at 36 percent, and 2005 at 32 percent. In general, ICA articles were more prevalent in recent years than earlier years. Using five-year intervals, the percentages of articles with ICA were 23 percent, 24 percent, and 29 percent for the periods 1991-1995, 1996-2000, and 2001-2005, respectively. It has been reported that the European Union is becoming more important as a scientific collaboration partner of both advanced and developing countries (Glänzel *et al.*, 1999). In the case of stroke-related research in Taiwan, international co-authorship also increased. The percentages of articles with ICA were 14 percent, 17 percent, and 23 percent for the periods 1991-1995, 1996-2000, and 2001-2005, respectively (Chuang *et al.*, 2007). Table III lists the ten most productive countries in total publications between 1991 and 2003, with ICA and CPP values. Among the 765 articles with CPP information from 1991 to 2003, international articles comprised 25 percent of the articles with a CPP of 29, compared to 75 percent from single countries, with a CPP of 13. International collaboration is a factor that attracts citations (de Granda Orive *et al.*, 2007). The most highly cited European papers were found to be the multinational papers (Narin *et al.*, 1991). The CPP values of the numbers of articles with international co-authorship were increased and significantly higher in the case of stroke-related research in Taiwan (Chuang *et al.*, 2007). Horizontal gene transfer-related articles with ICA had significantly higher CPP values. It would be reasonable to assume that more international collaboration would lead to more output due to the sharing of ideas and workloads (Chuang *et al.*, 2007). Meanwhile, single-country articles were produced by authors from 36 different countries, with the majority originating from the USA (192; 34 percent) with a CPP of 18 followed by

Country	SP	CPP	CP	CPP	TP	CPP
USA	192 (34)	18	97 (51)	24	289 (38)	20
Germany	85 (15)	11	61 (32)	27	146 (19)	18
UK	46 (8.0)	10	38 (20)	26	84 (11)	18
France	34 (5.9)	16	30 (16)	36	64 (8.4)	25
Canada	34 (5.9)	12	25 (13)	13	59 (7.7)	13
Japan	30 (5.2)	18	10 (5.2)	54	40 (5.2)	27
The Netherlands	11 (1.9)	7.9	16 (8.3)	44	27 (3.5)	29
Sweden	17 (3.0)	10	10 (5.2)	10	27 (3.5)	10
Spain	13 (2.3)	7.4	13 (6.8)	47	26 (3.4)	27
Australia	14 (2.4)	10	12 (6.3)	12	26 (3.4)	11

**Notes:** Figures in parentheses are percentages. SP, single country publications; CP, international collaborative publications; TP, total publications; CPP, citation per publication

**Table III.**  
Ten most productive countries in total publications from 1991 to 2005

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Germany (85; 15 percent) with a CPP of 11. Twenty countries contributed only one or two single-country articles. The country with the most international co-authorship was also the USA with 97 articles, comprising 51 percent of the total number of internationally co-authored articles, with an average CPP of 24. Germany was the country with the second greatest number of international collaborations, with 61 articles and an average CPP of 27. Nineteen countries contributed only one or two international collaborative articles. ICA articles with the highest TC2 values (Kunst *et al.*, 1997) were co-authored with researchers from France, Japan, Germany, The Netherlands, the UK, the USA, Poland, and Ireland. In addition, the USA was the most productive and cited country in patent ductus arteriosus treatments (Hsieh *et al.*, 2004), asthma in children (Chen *et al.*, 2005), biomedicine (Figueredo *et al.*, 2003), ophthalmic reserach (Ohba, 2005), and otolaryngology research (Cimmino *et al.*, 2005).

#### *Journals and subject categories*

The 765 articles with CPP were published in 213 journals during 1991 to 2003. Table IV shows the ten most published names of journals, the number of articles published by these journals, CPP, ranking order of CPP, IF, and ranking order of IF in a subject category. The journal that published the greatest number of articles was *Journal of Bacteriology*, with 53 articles, followed by *Proceedings of the National Academy of Sciences of the United States of America*, and *Journal of Molecular Evolution*. The 48 articles published in *Proceedings of the National Academy of Sciences of the United States of America* had the highest CPP (31) and the highest IF (10.231) among the top ten journals.

The 765 articles with subject category and CPP information were included in 58 subject categories. In the research history, HGT and recombination between two streptococcal lineages was first reported in the subject category of immunology and infectious diseases (Simpson *et al.*, 1992); later, the horizontal transfer of bacterial heavy metal resistance genes was first presented in the subject category of environmental-related fields (Dong *et al.*, 1998). Today, researchers in a number of unrelated fields are making observations related to HGT, leading to an unusual breadth of topics. Table V shows categories that had at least ten articles. The three top categories with the largest number of articles were *Microbiology* (279), *Biochemistry & Molecular Biology* (223), and *Genetics & Heredity* (180). All numerical analyses used integer counts, i.e. if an article was included in two or more different subject categories, each subject category was counted once, and thus in these instances the percentage will add up more than 100 percent.

#### *Distribution of KeyWords Plus*

KeyWords Plus provides search terms extracted from the titles of papers cited in each new article listed in the database in ISI (Garfield, 1990). KeyWords Plus substantially augments title-word and author-keyword indexing. Examination of KeyWords Plus revealed that 2,740 keywords were used in the 754 articles. Among them, 1,946 keywords (71 percent) appeared only once, 355 keywords (13 percent) appeared twice, and 134 keywords (4.9 percent) appeared three times. The large numbers of once-only keywords are caused by a wide disparity in research focus (such as “DNA gyrase”, “nitrogen-fixation”, “methane”, “rhizobium”, and “human skin”), a special material used in research (such as “*Bacillus sphaericus*”, “lacteriophage T7”, “L12” and “ribulose

Journal	Article	CPP	Ranking of CPP	Subject category	IF	Ranking
<i>Journal of Bacteriology</i>	53 (6.9)	12	41	Microbiology	4.167	16/86
<i>Proceedings of the National Academy of Sciences of the United States of America</i>	48 (6.3)	31	7	Multidisciplinary sciences	10.231	3/48
<i>Journal of Molecular Evolution</i>	41 (5.4)	9.2	57	Biochemistry and molecular biology	2.703	108/261
				Evolutionary biology		13/33
<i>Molecular Biology and Evolution</i>	36 (4.7)	13	39	Genetics and heredity	6.233	59/124
				Biochemistry and molecular biology		32/261
				Evolutionary biology		4/33
<i>Applied and Environmental Microbiology</i>	30 (3.9)	12	44	Genetics and heredity	3.818	15/124
				Biotechnology and applied microbiology		21/139
<i>FEMS Microbiology Letters</i>	24 (3.1)	5.7	99	Microbiology	2.057	19/86
<i>Gene</i>	23 (3.0)	8.0	69	Microbiology	2.694	53/86
<i>Molecular Microbiology</i>	22 (2.9)	14	36	Genetics and heredity	6.203	60/124
				Biochemistry & molecular biology		33/261
<i>Infection and Immunity</i>	20 (2.6)	11	48	Microbiology	3.933	11/86
				Immunology		22/115
<i>Microbiology-SGM</i>	18 (2.4)	7.8	70	Infectious diseases		8/43
				Microbiology	3.173	21/86

**Notes:** Figures shown in parentheses are percentages. CPP, citations per publication published in respective journals; IF, impact factor of the journal in 2005

**Table IV.**  
Core journals publishing  
horizontal gene  
transfer-related articles



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Subject category	Article	Percentage	TC2	CPP
Microbiology	279	36	2,537	9.1
Biochemistry and molecular biology	223	29	2,741	12
Genetics and heredity	180	24	2,073	12
Biotechnology applied microbiology	102	13	1,230	12
Evolutionary biology	97	13	1,013	10
Multidisciplinary sciences	75	9.8	3,587	48
Infectious diseases	43	5.6	457	11
Immunology	41	5.4	351	8.6
Cell biology	31	4.1	357	12
Biology	27	3.5	341	13
Plant sciences	24	3.1	176	7.3
Pharmacology and pharmacy	18	2.4	142	7.9
Virology	15	2.0	158	11
Biophysics	13	1.7	58	4.5
Ecology	12	1.6	89	7.4

**Table V.**  
Number of articles and  
CPP by subject category

**Notes:** TC2, times cited before the second full year since publication; CPP, citation per publication

1,5-bisphosphate carboxylase”), or a combination of some general topics, such as “DNA-sequence data”, “microbial gene identification” “evolutionary information”, “last common ancestor”, and “penicillin-resistant strains”.

Table VI shows 19 KeyWords Plus keywords that appeared at least 30 times. The most frequently used keyword was “*Escherichia coli*”, appearing in 29 percent of 754 articles published in 1991-2003 with a CPP of 14. Other frequently used keywords were

KeyWords Plus	No. of articles	Percent	TC2	CPP
<i>Escherichia coli</i>	221	29	3,143	14
Evolution	133	18	2,116	16
Sequence	118	16	1,629	14
Horizontal gene transfer	99	13	1,184	12
DNA	89	12	924	10
Identification	78	10	1,321	17
Expression	76	10	1,102	15
Nucleotide sequence	70	9.3	1,024	15
Bacteria	63	8.4	613	10
Gene	58	7.7	1,117	19
Cloning	54	7.2	631	12
Protein	53	7.0	1,149	22
Genes	49	6.5	1,055	22
Strains	47	6.2	560	12
Sequences	45	6.0	494	11
Genome	39	5.2	374	10
<i>Bacillus subtilis</i>	33	4.4	516	16
Proteins	32	4.2	557	17
Origin	31	4.1	567	18

**Table VI.**  
Frequency of KeyWords  
Plus keywords used

**Notes:** TC2, times cited before the second full year since publication; CPP, citation per publication

“evolution” at 18 percent, and followed by “sequence” at 16 percent, “horizontal gene-transfer” at 13 percent, and “DNA” 12 percent. The 53 articles with the KeyWords Plus keyword “protein” and the 49 articles with the KeyWords Plus keyword “genes” had the highest CPP (22) among the 19 keywords. In addition, “project”, “strands”, “terminators”, and “yeast artificial chromosomes” appeared once with the highest CPP of 499. Information regarding popular keywords is useful in understanding the research profile. “*Escherichia-coli*” is the most frequently used host bacterium in the HGT-related research. By “DNA” and “sequence” analysis, more evidence was found to show that “horizontal gene-transfer” might be an important driving force of “evolution”.

#### *Citation model*

For the period 1991-2003, the cumulative number of citations increased. In year of publication for all 765 articles, 969 citations were obtained, while three years after articles were published (including the year of publication), the cumulative number of citations (TC2) was 10,823. A model can be used to describe the relationship between the cumulative number of citations,  $C$ , and the article life,  $Y$  (Chiu and Ho, 2005). The model can be expressed as:

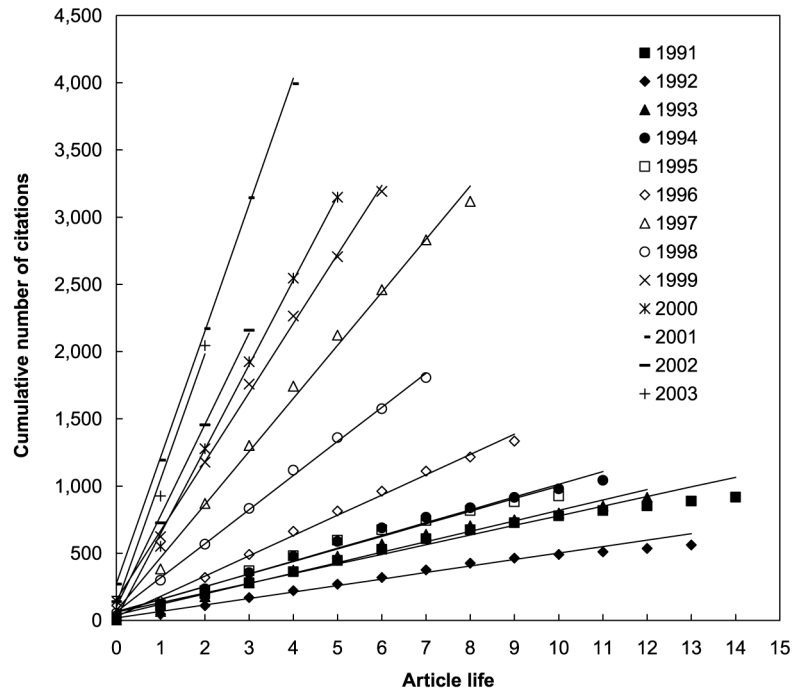
$$C = KY + S,$$

where  $K$  is the citation rate (number of times cited/year) and  $S$  is the visibility potential when a paper is published (number of times cited). Moreover,  $K$  is a measure of how quickly the “average article” in the field is cited.  $S$  shows how often the articles published in the field are cited in the year of publication.

This model fitting suggested that there were sustained constant citations in each year. Figure 3 shows that significant correlations between the yearly cumulative number of citations and the article life were made for the years 1991-2003, with the model having high coefficients of determination ( $r^2 > 0.984$ ). The results indicated that articles published in 2001 had the highest citation rate and visibility potential, followed by those published in 2003 and 1999, respectively (Table VII). In other words, 114 research articles published in 2001 had the highest impact potential and the greatest numbers of times cited each year after the articles were published.

#### **Conclusions**

Studies on HGT dealing with the SCI have increased during the past 15 years. Journal articles were the most frequent document type, with a lower citation per publication rate than reviews. The top three ranking countries in terms of total publication were the USA, Germany, and the UK. Articles with international co-authorship had higher visibility. Journals listed in the subject category of microbiology published the most articles. *Journal of Bacteriology* published the greatest number of articles. “*Escherichia coli*” was the most frequently used KeyWords Plus keyword. A linear model was successfully applied to describe the relationship between the cumulative number of citations and article life. Articles published in 2001 had the highest citation rate and visibility potential. The most frequently cited article was published in 1997 in *Nature*, which is the highest impact factor journal in the category of multidisciplinary sciences.



**Figure 3.**  
Relationships between the cumulative number of citations and age of articles with simulated models

Year	$K$ (number of times cited/year)	$S$ (number of times cited)	$r^2$
1991	71.7	61.2	0.984
1992	48.3	18.3	0.990
1993	77.6	42.0	0.981
1994	95.2	60.9	0.986
1995	93.5	64.5	0.980
1996	151	28.5	0.996
1997	395	71.3	0.996
1998	254	63.1	0.999
1999	514	152	0.998
2000	628	17.5	0.998
2001	940	274	0.999
2002	679	101	0.998
2003	933	116	0.987

**Table VII.**  
Citation model constants

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### Further reading

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