

SCIENTOMETRIC PORTRAIT OF NOBEL LAUREATE LELAND H. HARTWELL

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ABSTRACT

Leland H. Hartwell was honoured with the Nobel Prize in Physiology or Medicine (2001) at his 62 years age and at 41 years of research publishing career. The first contribution of the author was in 1961 at the age of 22. The number of his contributions in a year peaked in 1997 when it touched 8. He had 108 publications during 1961 – 2001 in domains: Molecular Biology of Cell Cycle Regulation (43), Genetics of Cell Division (48), Genomic Rearrangement and DNA Repair (9), Molecular Genetics of Yeast Cell Fission (5), and Drug Target Interaction (3) which were analysed for authorship pattern with his 101 collaborators. Most active researchers having number of publications with Leland H. Hartwell were : Weinert, T. A. (10), Garvik, B. M. (8), McLaughlin, C. S. (8), Jenness, D. D. (5). His productivity coefficient was 0.76 which clearly indicates that his productivity increased after 50 percentile age. Highest collaboration coefficient (1) for Leland H. Hartwell was found during 1963-1965, 1968-1969, 1977, 1981-1983, 1985-1990, 1996 and 1998-2001. Journals have been the most preferred channel of communication where, as many as 96 papers out of 108 have been published. The core journals publishing his papers were: *Cell* (14), *Genetics* (12), *Mol. Cell Biol.* (8), *J. Bacteriol.* (7), *J. Cell Biol.* (7), *Science* (7) *J. Mol. Biol.*(6), *Exp. Cell Res.* (5), and *Proc. Nat. Acad. Sci.*(5). Publication density is 2.63 and Publication concentration is 14.63. Most prolific keywords in titles of publications were: *Saccharomyces cerevisiae* , Yeast , Cell division cycle , RAD9, DNA Damage , Genes , Cell cycle, Genetic control , Check point (s) , Cell division , Mutant of Yeast.

KEYWORDS/DESCRIPTORS: Scientometric portrait; Scientometrics; Individual scientist; Publication productivity; Research collaboration; Bio-bibliometrics.

1. INTRODUCTION

All organisms consist of cells that multiply through cell division. An adult human being has approximately 100 000 billion cells, all originating from a single cell, the fertilized egg cell. In adults there is also an enormous number of continuously dividing cells replacing those dying. Before a cell can divide it has to grow in size, duplicate its chromosomes and separate the chromosomes for exact distribution between the two daughter cells. These different processes are coordinated in the cell cycle.

The Royal Swedish Academy of Sciences has awarded to Leland H. Hartwell as one of the three recipients of the Nobel Prize (2001) in Physiology or Medicine for their discoveries of "key regulators of the cell cycle". Hartwell's co-recipients of the Nobel Prize (2001) are Paul Nurse (born 1949), and Timothy Hunt (born 1943) from Imperial Cancer Research Fund, London.

They have made seminal discoveries concerning the control of the cell cycle. They have identified key molecules that regulate the cell cycle in all eukaryotic organisms, including yeasts, plants, animals and human. These fundamental discoveries have a great impact on all aspects of cell growth. Defects in cell cycle control may lead to the type of chromosome alterations seen in cancer cells. This may in the long term open new possibilities for cancer treatment.

Now a days individual scientists including the Nobel laureates, are becoming the focus of scientometric studies rather than gross statistical "macro" data [1].

Nobel prize is regarded as the most honourific recognition of scientific achievement. The prestige of Nobel prize is so great that it enhances the standing of nations and institutions as well as reputation of its "laureates" [2-4] .

The term 'Bio-bibliometrics' is currently used for a method of retrieving and visualizing biological information that uses co-occurrence of gene naming terms in Bio-Informetrics and Medical Sciences, to generate semantic links between genes [5]. Therefore, it is suggested that 'scientometric portrait' is the appropriate phrase for the studies on scientists and 'informetric portrait' for the researchers in other disciplines such as arts, humanities, and social sciences, instead of 'bio-bibliometrics' used in a few similar studies. [45,52,61]

2. OBJECTIVES

Leland H. Hartwell was taken as a case study for present scientometric analysis. Biographical details and a brief resume (Appendix-1) are well known.

This study highlights Leland H. Hartwell's:

- domainwise contributions,
- domainwise authorships,
- prominent collaborators,

- use of channels of communications, and
- documentation of keywords from titles of the papers.

The main concept of working on individual scientists especially on Nobel laureates is to provide an example of ‘Role Model Scientist’ for the younger generation to emulate and create scientific temper among them. Success of others may teach many things to follow their path. Knowledge is valuable for its own sake and research has cultural values. Desire of being creative is built in our genes. Who knows this effort may switch on genes for creativity in some of those who happen to read this article ! Narrating success stories have an encouraging effect.

3. MATERIALS AND METHODS

Scientific publications seem to provide the best available basis for measuring the research output. One of the first writers to suggest scientific papers as a measure of research productivity was Nobel laureate William Shokley [6] who was interested in measuring the research productivity among individuals within a group by analyzing their publications. A few scientometric studies on Nobel laureates [7-18] and others [19-54] have been published. The publication productivity, collaboration and authorship trend among eight Nobel laureates of past and present has been studied [55].

Present study is limited to the 108 papers by Leland H. Hartwell (1961-2001). The bibliographic fields were analysed by normal count procedure [56] for domains, authorships, journals, and keywords in the titles.

4. RESULTS AND DISCUSSION

4.1 Domainwise contributions

Leland H. Hartwell had research communications in the following domains:

- | | |
|-----|--|
| A = | Molecular Biology of Cell Cycle Regulation |
| B = | Genetics of Cell Division |
| C = | Genomic Re-arrangement and DNA Repair |
| D = | Drug Target Interaction |
| E = | Molecular Genetics of Yeast Cell Fission |

Hartwell had contributed 48 papers in the domain Genetics of Cell Division (1970 – 2001), 43 papers in Molecular Biology of Cell Cycle Regulation (1961 - 2001), nine in Genomic Re-arrangement and DNA Repair (1988 - 2000), five in Molecular Genetics of Yeast Cell Fission (1983 - 1990) followed by three papers in Drug Target Interaction (1997 - 1997). Domainwise profile of the annual growth of publications by Hartwell is presented in Figure-1.

4.2 Collaboratorship

Domainwise authorship pattern and number of publications and authorships in each domain are presented in Table-1. Two – authored Genetics of Cell Division papers were 20, followed by thirteen papers in Molecular Biology of Cell Cycle Regulation papers, six papers in Genomic Re-arrangement and DNA Repair and one paper in Molecular Genetics of Yeast Cell Fission. Three – authored Molecular Biology of Cell Cycle Regulation papers were 13, followed by nine papers in Genetics of Cell Division, four papers in Molecular Genetics of Yeast Cell Fission, one paper in Genomic Re-arrangement and DNA Repair. Four – authored Genetics of Cell Division papers were seven, followed by four papers in Molecular Biology of Cell Cycle Regulation, one paper each in Genomic Re-arrangement and DNA Repair and Drug Target Interaction. Five – authored Molecular Biology of Cell Cycle Regulation papers were two, followed by one paper in Drug Target Interaction. One paper each in Genetics of Cell Division and Genomic Re-arrangement and DNA Repair were six-authored and nine-authored respectively. Eleven-authored Molecular Biology of Cell Cycle Regulation papers were two. Fourteen – authored one paper was in Drug Target Interaction.

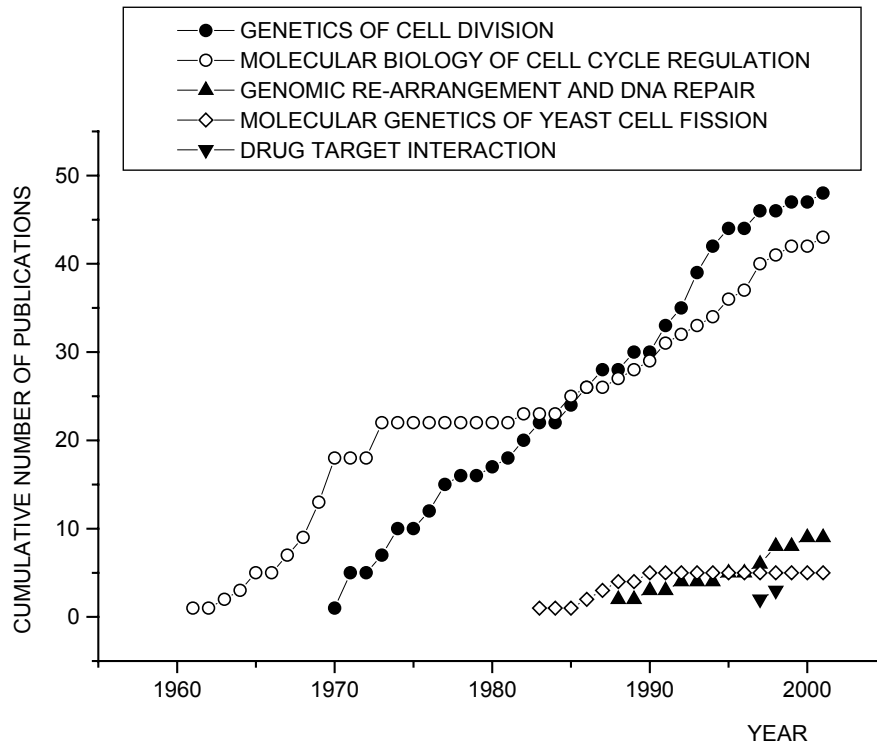


Fig. 1. Domainwise publication productivity of Leland H. Hartwell

Leland H. Hartwell had 20 single – authored papers in various domains such as Genetics of Cell Division (11) and Molecular Biology of Cell Cycle Regulation (9). Year - wise productivity of Leland H. Hartwell is shown in Table-2 and Figure-2. He published his first paper in the year 1961. His 81.48 per cent of papers were collaborative.

Twentieth century has seen a tremendous collaborative research among individual scientists working in groups within and across the geographic boundaries of a country, which enhanced the ability of scientists to put in their brain collectively and make significant progress in their respective domains of specialisation. Collaboration is inevitable in natural sciences and multidisciplinary areas to make significant advances and break throughs.

Whatever the advances have been made today are the results of endeavours of individual scientists as mentors [57-59] .

To measure the collaborative research pattern, a simple indicator called Collaboration Coefficient [60] (number of collaborative papers divided by total number of papers) is used. Highest collaboration coefficient (1.00) for Leland H. Hartwell was found in 1963-1965, 1968-1969, 1977, 1981-1983, 1985-1990, 1996 and 1998-2001.

The Productivity Coefficient [61] is the Ratio of the productivity age (corresponding to the 50 percentile productivity) to the total productivity life. He had highest number of collaborative papers (7) in 1997 and published highest (8) number of papers in 1997. He did not publish any paper in the years 1962, 1966, 1972, 1975, 1979, and 1984.

Table 1: Domainwise productivity of number of papers and authorship pattern of the Nobel laureate Leland H. Hartwell (1961 – 2001)

No. of authored papers	Domains					Total No. of papers	%	No of Authorships	%
	A	B	C	D	E				
1-authored	9	11				20	18.51	20	6.68
2-authored	13	20	6		1	40	37.03	80	26.75
3-authored	13	9	1		4	27	25.00	81	27.10
4-authored	4	7	1	1		13	12.04	52	17.39
5-authored	2			1		3	2.78	15	5.02
6-authored		1				1	0.93	6	2.01
9-authored			1			1	0.93	9	3.01
11-authored	2					2	1.85	22	7.36
14-authored				1		1	0.93	14	4.68
Total	43	48	9	3	5	108	100	299	100
Percentage	39.82	44.44	8.33	2.78	4.63	100	A = Molecular Biology of Cell Cycle Regulation B = Genetics of Cell Division C = Genomic Re-arrangement and DNA Repair D = Drug Target Interaction E = Molecular Genetics of Yeast Cell Fission		
Authorship per paper	2.84	2.33	3.11	7.67	2.8				

Table 2: Collaboration pattern of Leland H. Hartwell

Age of Leland H. Hartwell	Year	Number of papers under various authorships						Collaboration Coefficient	Publishing Career Age
		Single-authored	Cumulative	Multi-authored	Cumulative	Total	Cumulative		
22	1961	1	1			1	1	0	1
23	1962		1				1	0	2
24	1963		1	1	1	1	2	1	3
25	1964		1	1	2	1	3	1	4
26	1965		1	2	4	2	5	1	5
27	1966		1		4		5	0	6
28	1967	1	2	1	5	2	7	0.5	7
29	1968		2	2	7	2	9	1	8
30	1969		2	4	11	4	13	1	9
31	1970	2	4	4	15	6	19	0.67	10
32	1971	2	6	2	17	4	23	0.5	11
33	1972		6		17		23	0	12
34	1973	2	8	4	21	6	29	0.67	12
35	1974	1	9	2	23	3	32	0.67	14
36	1975		9		23		32	0	15
37	1976	1	10	1	24	2	34	0.5	16
38	1977		10	3	27	3	37	1	17
39	1978	1	11		27	1	38	0	18
40	1979		11		27		38	0	19
41	1980	1	12		27	1	39	0	20
42	1981		12	1	28	1	40	1	21
43	1982		12	3	31	3	43	1	22
44	1983		12	3	34	3	46	1	23
45	1984		12		34		46	0	24
46	1985		12	4	38	4	50	1	25
47	1986		12	4	42	4	54	1	26
48	1987		12	3	45	3	57	1	27
49	1988		12	4	49	4	61	1	28
50	1989		12	3	52	3	64	1	29
51	1990		12	3	55	3	67	1	30
52	1991	1	13	4	59	5	72	0.8	31
53	1992	3	16	1	60	4	76	0.25	32
54	1993	1	17	4	64	5	81	0.8	33
55	1994	1	18	3	67	4	85	0.75	34
56	1995	1	19	4	71	5	90	0.8	35
57	1996		19	1	72	1	91	1	36
58	1997	1	20	7	79	8	99	0.86	37
59	1998		20	4	83	4	103	1	38
60	1999		20	2	85	2	105	1	39
61	2000		20	1	86	1	106	1	40
62	2001		20	2	88	2	108	1	41
	Total	20		88		108			
	Percentage	18.52		81.48		100			

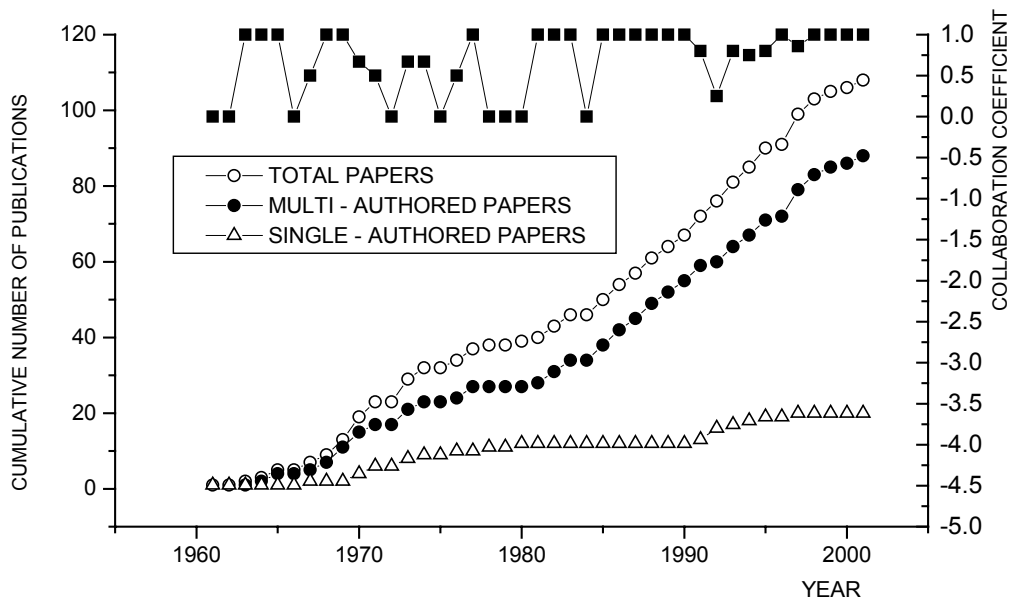


Fig. 2. Growth pattern of publications by Leland H. Hartwell and collaboration coefficients

Researchers and their authorships in collaboration with Leland H. Hartwell in chronological order of their association (starting with first paper publication year) are documented in Table-3 and depicted in Figure-3.

Table 3: Domainwise and Chronological profile for the Nobel Laureate Leland H. Hartwell and his collaborators during 1961 - 2001

Sl. No.	Authors	Domains					Period of collaboration FPY-LPY	TY	No. of Authorship
		A	B	C	D	E			
1	Hartwell , L H	43	48	9	3	5	1961-2001	41	108
2	Magasanik, B	2					1963-1964	2	2
3	Dulbecco, R	2					1965-1965	1	2
4	Vogt, M	2					1965-1965	1	2
5	Hutchison, C	3					1967-1970	4	3
6	McLaughlin, C S	8					1968-1970	3	8
7	Magee, P T	1					1969-1969	1	1
8	Martin, T E	1					1970-1970	1	1
9	Terry, H	1					1970-1970	1	1
10	Trudy, M	1					1970-1970	1	1
11	Warner, J R	1	1				1970-1973	4	2
12	Culotti, J	1	3				1970-1974	5	4
13	Reid, B J		3				1970-1977	8	3
14	Hereford, L M		3				1971-1974	4	3
15	Bucking-Throm, E	1		1			1973-1973	1	2

16	Duntze, W	1				1973-1973	1	1	
17	Manney, T R	1				1973-1973	1	1	
18	Mortimer, R K	1				1973-1973	1	1	
19	Shulman, R W		1			1973-1973	1	1	
20	Pringle, J R		3			1974-1981	8	3	
21	Unger, M W		2			1976-1977	2	2	
22	Johnston, G C		1			1977-1977	1	1	
23	Dutcher, S K		4			1982-1983	2	4	
24	Wood, J S	1	2			1982-1986	5	3	
25	Garvik, B M	2	5	1		1982-2001	20	8	
26	Burkholder, A C	2			2	1983-1986	4	4	
27	Jeness, D D	1				4	1983-1988	6	5
28	Weinert, T A		7	3			1984-1988	5	10
29	Kent, J C		1				1985-1985	1	1
30	Smith, D		1				1985-1985	1	1
31	Koshland, D		3				1985-1987	3	3
32	Carson, M	1	1				1985-1995	11	2
33	Meeks-Wagner, D		2				1986-1986	3	2
34	Fitzgerald-Hayes, M		1				1987-1987	1	1
35	Goldman, B					1	1987-1987	1	1
36	Rutledge, L		2				1987-1987	1	2
37	Cross, F	2					1988-1988	1	2
38	Jackson, C L	3			1		1988-1991	4	4
39	Konopka, J B	2				1	1988-1991	4	3
40	Gasdaska, P	1					1989-1998	10	1
41	Burke, D	1					1989-1989	1	1
42	Neiman, P E	1					1991-1991	1	1
43	Seeley, T		1				1991-1991	1	1
44	Kadyk, L		3	1			1991-1994	4	4
45	Brown, P O		2	1	1		1991-1998	8	4
46	Brewer, B J	1					1993-1993	1	1
47	Carol, Sibley	1					1993-1993	1	1
48	Friedman, Jan M	1					1993-1993	1	1
49	Goetsch, L		1				1993-1993	1	1
50	Helga, V	1					1993-1993	1	1
51	Manoil, C C	1					1993-1993	1	1
52	Toriello, H V	1					1993-1993	1	1
53	Sibley, C H	1			1		1993-1997	5	2
54	Kastan, M B		1				1994-1994	1	1
55	Kiser, G L		1				1994-1994	1	1
56	Pryciak, P	2					1995-1995	1	2
57	Dorer, R	3					1995-1997	3	3
58	Schrick, K	2					1995-1997	3	2
59	Paulovich, A G		1	3			1995-1998	4	4
60	Peter, M	1					1996-1996	1	1
61	Prychiak, P M	1					1996-1996	1	1
62	Boone, C	1					1997-1997	1	1
63	Galgoczy, D J		1				1997-1997	1	1
64	Kim, J	1					1997-1997	1	1
65	Margulies, B			1			1997-1997	1	1
66	Toczyski, D P		2				1997-1997	1	2
67	Tyler, K	1					1997-1997	1	1
68	Vasquez, B				1		1997-1997	1	1

69	Wooden, J M				1		1997-1997	1	1
70	Friend, S H			1	2		1997-2000	4	3
71	Roberts, C J			1	2		1997-2000	4	3
72	Szankasi, P			1	1		1997-2000	4	2
73	Armour, C D	2		1			1998-1998	1	3
74	Bassett, D E Jr.		1		1		1998-1998	1	2
75	Bennett, H A			1	1		1998-1998	1	2
76	Burchard, J				1		1998-1998	1	1
77	De Risi, J L	1			1		1998-1998	1	2
78	Iyer, V R				1		1998-1998	1	1
79	Marton, M J				1		1998-1998	1	1
80	Masui, Y	1					1998-1998	1	1
81	Meyer, M R				1		1998-1998	1	1
82	Nurse, P	1					1998-1998	1	1
83	Slade, D				1		1998-1998	1	1
84	Stoughton, R				1		1998-1998	1	1
85	Goldberg, M L	1					1999-1999	1	1
86	Hood, Leroy	1					1999-1999	1	1
87	Hopfield, J J		1				1999-1999	1	1
88	Lee, M	1					1999-1999	1	1
89	Leibler, S		1				1999-1999	1	1
90	Michael, L	1					1999-1999	1	1
91	Reynolds, Ann E	1					1999-1999	1	1
92	Silver, L M	1					1999-1999	1	1
93	Veres, R C	1					1999-1999	1	1
94	Dunstan, H M			1			2000-2000	1	1
95	Jensen, E L	1	1				2000-2000	1	2
96	Ludlow, C			2			2000-2000	1	2
97	Nguyen, D K			1			2000-2000	1	1
98	Schieltz, D M		1				2000-2000	1	1
99	Simon, J A			1			2000-2000	1	1
100	Emili, A		1				2001-2001	1	1
101	Hartman, J	1					2001-2001	1	1
102	Yates, J R		1				2001-2001	1	1
	Total	120	114	30	24	11			299

(A = Molecular Biology of Cell Cycle Regulation; B = Genetics of Cell Division; C = Genomic Re-arrangement and DNA Repair; D = Drug Target Interaction ; E = Molecular Genetics of Yeast Cell Fission ; FPY = First Publication Year; LPY = Last Publication Year; and TY = Total Years)

4.3 Domainwise authorships

Table 3 shows author productivity and distribution of authors in various domains. The research group of Leland H. Hartwell had the credits as number of authorships in various domains: Molecular Biology of Cell Cycle Regulation (120), Genetics of Cell Division (114), Genomic Re-arrangement and DNA Repair (30), Drug Target Interaction (24), and Molecular Genetics of Yeast Cell Fission (11).

Table 4 : Domainwise Publication Productivity of the Nobel laureate Leland H. Hartwell and his Collaborators (1961-2001)

No. of Papers (p)	Domains					No. of Authors (n)	Total Authorships (nxp)	Prominent Collaborators
	A	B	C	D	E			
1	31	15	4	8	1	59	59	
2	18	12	5	5	-	20	40	
3	11	14	3	4	1	11	33	
4	6	13	5	4	-	7	28	Burkholder, A C.; Brown, P O.; Culotti, J. Dutcher, S. K.; Jackson, C. L.; Kadyk, L.; and Paulovich, A. G.;
5	1	-	-	-	4	1	5	Jenness, D. D.
8	10	5	1	-	-	2	16	Garvick, B. M. and McLaughlin, C. S.
10	-	7	3	-	-	1	10	Weinert, T. A.
108	43	48	9	3	5	1	108	Hartwell, Leland H.
Total	120	114	30	24	11	102	299	

(A = Molecular Biology of Cell Cycle Regulation; B = Genetics of Cell Division; C = Genomic Re-arrangement and DNA Repair; D = Drug Target Interaction ; and E = Molecular Genetics of Yeast Cell Fission)

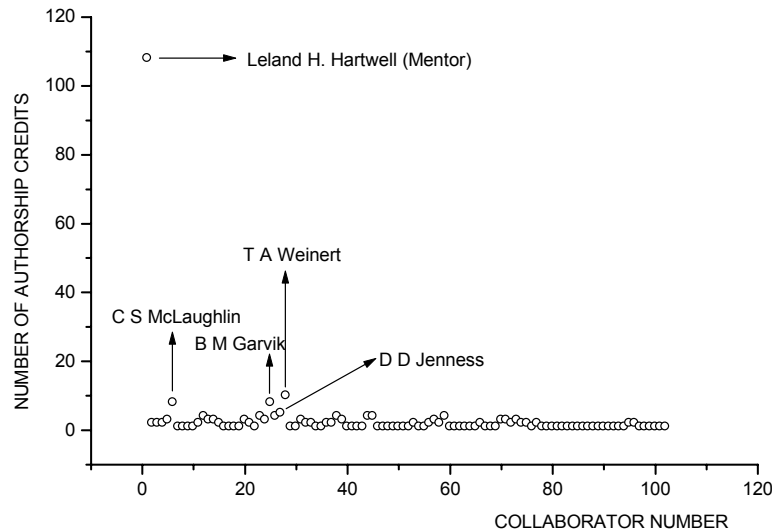


Fig.3. Authorship Credits to Collaborators with Leland H. Hartwell

4.4 Collaborator dynamics

Highest collaborators were found in the eighth quinquennium (1996-2000) publications where 40 new collaborators and eight old collaborators including himself continued to collaborate. Quinquenniumwise number of collaborators found were four during 1961-1965, ten during 1966-1970, eleven during 1971-1975, five during 1976-1980, twelve during 1981-1985, seventeen during 1986-1990, and twenty four during 1991-1995.

Most active researchers with number of publications with Leland H. Hartwell (Table-4) were : Weinert, T. A. (10), Garvik, B. M. (8), McLaughlin, C. S. (8), and Jenness, D. D. (5). Seven scientists had collaboration in four papers each were: Dutcher, S. K.; Jackson, C. L.; Kadyk, L.; Paulovich, A. G.; Burkholder, A C.; Brown, P O.; and Culotti, J. Eleven scientists had collaboration in 3 papers each. Twenty scientists had collaboration in two papers each. Fifty nine scientists could collaborate in only one paper each. Total number of authors in the research group were 102 and total number of authorships were 299.

4.5 Use of channels of communication

Distribution of Leland H. Hartwell's 108 publications were spread over 29 journals, 7 edited books, 2 books, 2 symposia and 1 lecture. Channelwise scattering of publications of Leland H. Hartwell is provided in Table-5 and Figures 4 and 5. He has published 14 papers in *Cell* (1983 – 1997), 12 papers in *Genetics* (1969 – 1998), 8 papers in *Mol. Cell. Biol.* (1983 – 1996), 7 papers each in *J. Bacteriol.* (1967 – 1973), *Science* (1974 – 2001), and *J. Cell Biol.* (1977 –1995), and 6 papers in *J. Mol. Biol.* (1963 – 1976). Publication density [62] is 2.63 (Publication density is defined as the ratio of total number of papers published to the total number of journals in which the papers were published). Publication concentration is 14.63 (Publication concentration is the ratio in percentage of the channels having half of the papers published to the total number of channels in which those papers were published).

Table 5 : Channels Preferred by Leland H. Hartwell for Dissemination of his Research during 1961 - 2001

Sl. No.	Channel of Communication	No. of Papers	Cumulative	FPY - LPY	TY	IF
1	<i>Cell</i>	14	14	1983 - 1997	15	29.22
2	<i>Genetics</i>	12	26	1969 - 1998	30	4.803
3	<i>Mol. Cell. Biol.</i>	8	34	1983 - 1996	14	9.836
4	<i>J. Bacteriol.</i>	7	41	1967 - 1973	7	3.984
5	<i>Science</i>	7	48	1974 - 2001	28	23.33
6	<i>J. Cell Biol.</i>	7	55	1977 - 1995	19	12.92
7	<i>J. Mol. Biol.</i>	6	61	1963 - 1976	14	5.826
8	<i>Exp. Cell Res.</i>	5	66	1971 - 1977	7	5.096
9	<i>Proc. Nat. Acad. Sci.</i>	5	71	1968 - 1985	18	10.9
10	<i>Nature New Biol.</i>	3	74	1971 - 1991	21	-
11	<i>Nature Medicine</i>	2	76	1998 - 1998	1	27.91
12	<i>Nature</i>	2	78	1997 - 1999	3	27.96
13	<i>Mol. Gen. Genetics</i>	2	80	1970 - 1970	1	2.472
14	<i>Ann. Rev. Cell Biol.</i>	1	81	1988 - 1988	1	-
15	<i>Ann. Rev. Genetics</i>	1	82	1970 - 1970	1	14.31

16	<i>Bacteriol. Rev.</i>	1	83	1974 - 1974	1	
17	<i>Cold Spr. Harb. Symp. Quant. Biol.</i>	1	84	1994 - 1994	1	0.896
18	<i>Cancer</i>	1	85	1992 - 1992	1	3.909
19	<i>Cancer Res.</i>	1	86	2000 - 2000	1	8.302
20	<i>Clinical Cancer Research</i>	1	87	1994 - 1994	1	-
21	<i>Genes Dev.</i>	1	88	1994 - 1994	1	-
22	<i>J. Biol. Chem.</i>	1	89	1970 - 1970	1	7.25
23	<i>J. Cell. Sci. Suppl.</i>	1	90	1989 - 1989	1	6.213
24	<i>Mol. Biol. Cell</i>	1	91	1992 - 1992	1	7.7
25	<i>Molecular Cell</i>	1	92	2001 - 2001	1	16.61
26	<i>Nature Genetics</i>	1	93	1998 - 1998	1	29.6
27	<i>Nucleic Acids Res.</i>	1	94	1985 - 1985	1	6.373
28	<i>Parasitology</i>	1	95	1997 - 1997	1	2.114
29	<i>Rec. Adv. Yeast Mol. Biol.</i>	1	96	1982 - 1982	1	-
30-41	Others in Books, Conf. etc.	12	108			

(FPY = First Paper Year, LPY = Last Paper Year, TY = Total Years, and IF=Impact Factor taken from *Journal Citation Reports - 2002*)

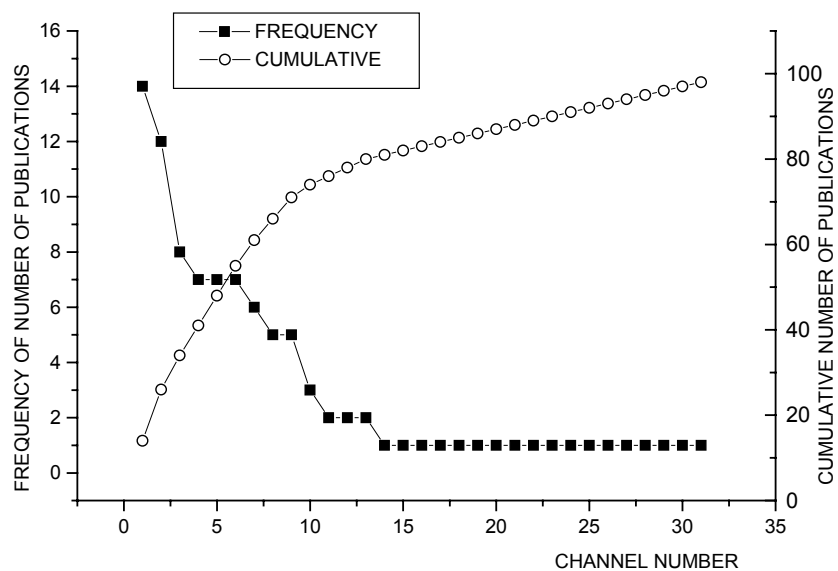


Fig. 4. Bradford – Zipf Bibliograph for Leland H. Hartwell

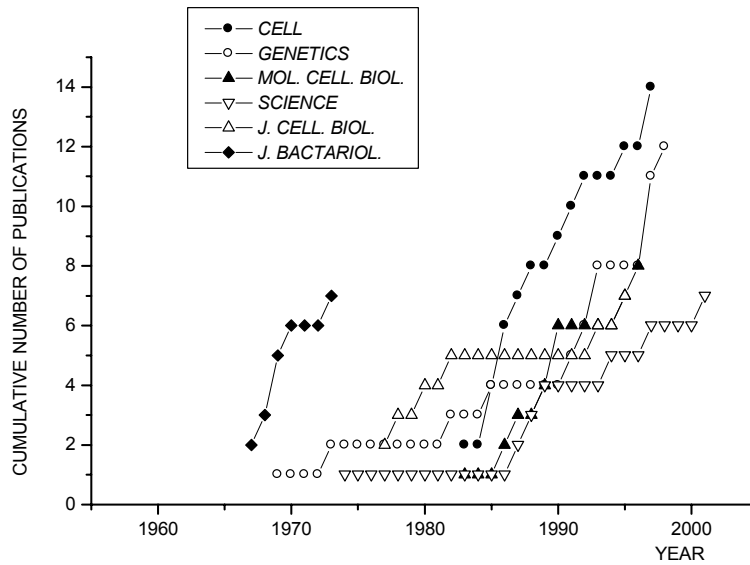


Fig. 5. Growth of the publications by Leland H. Hartwell preferentially contributed to six journals

4.5.1 Distribution of Leland H. Hartwell's publications in different types of communication channels

It is clearly evident from the Table-6 that his 88.88 percentage of publications were published in scientific journals followed by 11.12 percentage of publications in books, symposia, lecture etc.

Table 6 : Distribution of Leland H. Hartwell's Publications in Different Types of Communication Channels during 1961 - 2001

Document Types	No. of Papers
Journals articles	96
Edited books	7
Books	2
Symposia	2
Lecture	1
Total	108

4.6 Keyword Tomography

The recent study on Database Tomography [63] for Research Impact Assessment is interesting. Titles of publications convey precisely the thought contents of the papers. The potency of information concentrated on the titles of the papers is more than the rest of the sections of the papers. Therefore if a word occurs more frequently than expected it to occur, then it reflects the emphasis given by the author about the domain of his research. These important words called ‘keywords’ are one of the best indicators to understand and to grasp instantaneously the thought content of the papers, methodologies used and areas of research addressed to. The keyword frequencies appeared in the titles of the papers is provided in Tables-7 and 8. High frequency keywords were: *Saccharomyces cerevisiae* (41), Yeast (17), Cell division cycle (8), RAD9 (8), DNA Damage (7), Genes (7), Cell cycle (6), Genetic control (6), Cell division (5) and Mutant of yeast (5), and Checkpoint(s) (5).

Table 7 : Keyword Frequency from the Titles of Leland H. Hartwell (1961 – 2001)

Keywords	Frequency
<i>Saccharomyces cerevisiae</i>	41
Yeast	17
Cell division cycle	8
RAD9	8
DNA Damage	7
Genes	7
Cell cycle	6
Genetic control	6
Checkpoint(s)	5
Cell division	5
Mutant of yeast	5
Control(s)	4
Mitotic chromosome transmission	4
Alpha-factor pheromone	3
Cancer	3
Conjugation	3
DNA synthesis	3
Fidelity	3
Genetic Analysis	3
Yeast cell cycle	3
Alpha-factor receptor	2
<i>Bacillus subtilis</i>	2
Cdc mutants	2
Cell cycle arrest	2
Cell cycle checkpoints	2
Cell Cycle Control	2
Cell cycle response	2
Cellular DNA synthesis	2
Courtship	2

DNA repair	2
DNA replication	2
Macromolecule synthesis	2
Mating	2
Mutants	2
Pheromone	2
Polyoma virus	2
Protein synthesis	2
RAD17	2
RAD24	2
Sister chromatids	2
Temperature sensitive	2

Table 8 : Keywords appearing only once in the titles of publications by Leland H. Hartwell during 1961 – 2001

Alpha-factor binding; Alpha-pheromone receptor; Activate; Adaption; AKR1; Analysis; Anaphase; Anaphasespindle elongation; Anti-cancer drugs; Anticancer agents; Antimalaria drugs; Asf1; Basic scientist; Binding; Binding sites; Biochemical genetics; Biochemical pathways; Bud emergence; Budding yeast; Buffering; C-terminus; Cancer Cells; Cancer research; Candidate effector; Carcinogenesis; Cdc13 mutants; CDC5; Cell cycle checkpoint; Cell cycle controls; Cell cycle events; Cell cycle genetics; Cell mutants; Cell polarity; Cell shape; Cell-cell interaction; Cells; Checkpoint mutants; Checkpoint Protein; Checkpoint regulates; Chemical and genetic evidence; Chromatin Assembly Factor; Chromosome segregation; CKII; Control of G; Coordination of growth ; Cycloheximide; Cytokinesis; Default pathway; Defective; Defective DNA synthesis; Defective methionyl-tRNA synthetase; Defects; Deoxyribonucleic acid synthesis; Dependence of mitosis; Dependent pathway; Dicentric minichromosomes; Differential toxicities; Diffusible sex factor; Dihydrofolate reductase; Disease research; Dissociation constant; DNA microarrays; Dominant effects; Drug target; Dynamic Interaction; Enzyme repression; Enzyme synthesis; Essential gene; Extragenic suppression; Fluctuation; Forbeck Cancer Forum; Fred Hutchinson Cancer Research Center; G protein; Gbg complex; Gene controls; Gene expression; Gene function controls; Gene functions; Gene products; Genetic analysis; Genetic approaches; Genetic control; Genetic Instability; Genetic perspective; Genetic variation; Genetics; Genomes; Genomic Instability; Genomic integrity; Genomics; Haploid yeast cell cycles; Haploid yeast cells; Histidase induction; Histone dimer sets; Homologs; Hormonal control; Human disease; Implications; Induction; Isolation; Isoleucyltransfer ribonucleic acid synthetase; Karyogamy; Lsoleucyl-tRNA synthetases; Malignant instability; Map distance separating; MAP kinase cascade ;Mate; Mating Behavior; Mating partner discrimination; Mating partners; MEC3; Messenger RNA synthesis; Methionyl-tRNA; MIF2; Minichromosomes; Mitotic checkpoints genes; Mitotic chromosome reproduction; Mitotic fidelity; Mitotic transmission; Modular cell biology; Molecular; Molecular basis of histidase induction; Molecular biology; Mouse Kidney cells; Mutants unresponsive; Normal stoichiometry; Novel signal transduction pathway; Nuclear fusion; Nucleus; Oncogenes; Origins of human cancer; Pathway; Periodic density; Permeabilized yeast mutants; Pheromone gradients; Pheromone receptor; Pheromone response; Pheromone signal; *Plasmodium falciparum*; Polypeptide chains; Polypeptide mating hormone; Polyribosome stability; Practical Approach; Principles; Puzzle; Rad1mutants; Rad53; Rapid Inhibition; Rate of progression; Recombination; Recombinational repair; Regulation of mating; Replication; Replication-dependent; Response to pheromone; Reversible arrest; Ribonucleic acid production; Ribonucleic acid synthesis; Ribosomal proteins; Ribosome formation; RII region of bacteriophage T4B; Robust view; Role of protein synthesis; Role of yeast; S phase; Sequential function; Sequential gene function; Seven genes; Signal transduction; Single-stranded DNA; Sister minichromosome DNA; Special restrictions; Specific signal; STE2 gene; Structural properties; Synchronization; Synchronous cultures; Telomere elongation; Telomeres; Temporal; Ten genes; Theoretical biology; Tubulin overexpression; Two cistrons; Two east mutants ; Unequal division; UV-induced DNA damage; Yeast DNA; Yeast genetics; Yeast mutant defective; and Yeast spheroplasts.

As James Clerk Maxwell said: “It is when we take some interest in the great discoverers and their lives that science becomes enduring, and only when we begin to trace the developments of ideas that it becomes fascinating.” Through the analysis of synchronous references one can trace the origin and development of the ideas related to the topic of research. Already research work has been initiated in this area by taking into consideration the life - time publications of an individual scientist [64] and Nobel lectures as pilot studies on synchronous references in each paper [65]. Eponymous citations to an individual scientist should also be considered while counting citations [66] through the *Science Citation Index*.

5. CONCLUSION

Leland H. Hartwell has published 108 papers during 1961–2001. The percentage of collaborative work (81.48) of the scientist was found to be very high as he had as many as 101 collaborators whom he guided as a mentor. His collaboration coefficient 1.0 was found during 1963-1965, 1968-1969, 1977, 1981-1983, 1985-1990, 1996 and 1998-2001. Hartwell worked in highly specialised fields such as Molecular Biology of Cell Cycle Regulation; Genetics of Cell Division; Genomic Re-arrangement and DNA Repair; Drug Target Interaction; and Molecular Genetics of Yeast Cell Fission. He has received several professional awards and honours which is indicative of his highly specialized and original work in his field. His papers have been scattered in 31 high impact factor scientific journals. It will be very interesting if one attempts to study the sociological aspects and citation studies on Leland H. Hartwell which may give many new insights into his scientific career.

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BIRTH: October 30, 1939; Los Angeles, California

EDUCATION:

Institution Attended	Degree	Year	Mentor
California Institute of Technology	B.S.	1961	
Massachusetts Institute of Technology	Ph.D.	1964	Boris Magasanik
Salk Institute for Biological Studies	1964	1965	Renato Dulbecco

PROFESSIONAL RECORD:

Institution	Position	From - To
University of California	Assistant, Assoc. Professor	1965-1968
University of Washington	Associate & Full Professor (1973)	1968-present
Stanford University	Sabbatical	1983
Fred Hutchinson Cancer Research Center	Sabbatical	1984
Fred Hutchinson Cancer Research Center	Member, Sr. Advisor Sci. Affairs	1996
Fred Hutchinson Cancer Research Center	President and Director	1997

PROFESSIONAL AWARDS:

1973 Eli Lilly Award in Microbiology and Immunology
 1983-1984 Guggenheim Awardee and American Cancer Society Scholar
 1990-present American Cancer Society Research Professor Genetics
 1990 National Institutes of Health Merit Award
 1991 General Motors Sloan Award
 1991 Hoffman LaRoche Mattia Award
 1992 Gairdner Foundation International Award
 1992 University of Chicago Simon Shubitz Award
 1993 Brandeis University Rosenstiel Award
 1994 Sloan-Kettering Cancer Center Katherine Berkan Judd Award
 1994 Genetics Society of America Medal
 1995 MGH Warren Triennial Prize
 1995 Columbia University Horwitz Award
 1995 Keith Porter Award, Amer Soc Cell Biology
 1996 Passano Award

1996 Carnegie Mellon Dickson Prize
1998 Albert Lasker Basic Medical Research Award
1998 Brinker International Award for Basic Science - Susan G. Komen Breast Cancer Foundation
1999 California Institute of Technology - Distinguished Alumni Award
1999 City of Medicine Award
1999 American Cancer Society Medal of Honor
2000 Léopold Griffuel Prize - Association pour la Recherche sur le Cancer, France
2000 The Massry Prize – The Meira and Shaul G. Massry Foundation
2001 The Nobel Prize in Physiology or Medicine

MEMBERSHIP OF PROFESSIONAL SOCIETIES:

American Society of Microbiology
American Academy of Microbiology
Genetics Society of America
American Society for Cell Biology
National Academy of Sciences
American Association for Cancer Research
American Academy of Arts & Sciences

PROFESSIONAL SERVICES:

Genetics Study Section, NIH, 1980-1982
Eukaryotic Genetics Study Section, NSF, 1986
President, Genetics Society of America, 1991
National Advisory General Medical Sciences Council, 1991-1995
NCI Cancer Genetics Working Group, 1996-
NHGRI Scientific Planning Subcommittee, 1997-
NIEHS Genome Project Working Group, 1997-
HHMI Genetics Program Review Committee, 1998-
BioLab National Advisory Board, 2000

MEMBER OF EDITORIAL BOARDS:

Molecular & Cellular Biology
Journal of Cell Biology, 1988-1991
Molecular Biology of the Cell, 1991-1993