Essays of an Information Scientist, Vol:5, p.428-436, 1981-82 Current Contents, #9, p.5-13, March 1, 1982

Current Comments

The 1,000 Most-Cited Contemporary Authors. Part 2A. Details on Authors in the Physical and Chemical Sciences and Some Comments about Nobels and Academy Memberships

Number 9 March 1, 1982

Recently, we published a first look at the 1,000 most-cited contemporary scientists.[1] This part of the continuing series of essays is divided into two sections. First, we will present some statistics on the academy memberships of the entire list of 1,000 authors. In the second section there is a discussion of the 214 authors in the physical and chemical sciences. Future parts of this essay will cover authors in other fields, primarily life sciences. Then a concluding essay will provide a look at the institutional affiliations of the entire 1,000.

It is important to restate the ground rules for this study. It was limited to authors who published journal articles from 1965 to 1978 that were indexed in *Science Citation Index® (SCI®)*, hence the "contemporary" designation. Since data for cited books were not included, certain authors are excluded.

The list was based on "all author" data. Each author of a cited article was treated as a first author regardless of his or her position in the article's by-line. A glance at the data in the physical and chemical sciences section highlights the importance of this point. Generally, authors in this section averaged more cited papers as coauthors than as primary authors. In addition, the majority averaged more citations to coauthored papers than they received to papers on which they were first author.

Only 373 of the 1,000 authors on the list are members of one or more national academies. As a further illustration of the Matthew effect,[2] we found that less than half—161—of these authors are members of just one academy. More than half are members of two or more (123 of two, 48 of three, and 21 of four). Twenty authors belong to more than four academies. The code letter M in Table 1 indicates this fact. These authors are listed along with their memberships in Table 2. A key to their memberships and the number of authors in each academy appear in Table 3. R.B. Woodward, now deceased, was a member of 12, while T. Caspersson is a member of 11.

Of the 1,000 authors listed in Part 1 of this essay,[1] 240 are members of the US National Academy of Sciences (NAS). Seventy-four scientists on the list are members of the Royal Society of London, the equivalent of the UK's national academy. The US Institute of Medicine constitutes a national academy of medicine and has 31 authors on the list.

Less well known to most readers and not regarded as an official academy is the American Academy of Arts and Sciences. It honors men and women for their achievements in the mathematical and physical sciences, biological sciences, social arts and sciences, and the humanities. One hundred ninety-one authors on this list belong to this academy.

We have also included the American Philosophical Society (APS). It also is not, strictly speaking, an academy. Membership is limited to outstanding

Table 1: The most-cited scientists in the physical and chemical sciences, listed alphabetically by fields. Date of birth is in parentheses. A=total citations. B=first author citations. C=citations as a secondary author. D=total number of cited papers. E=first author papers. F=secondary-authored papers. G=citations/paper. Academy memberships are indicated by a code in column H. A key to these codes appears in Table 3. Asterisks indicate Nobel prizewinners.

Aeronomy	A	B	C	D	E	F	G	H
AKASOFU SI (1930)	2536	1111	1425	183	69	114	13	
FERGUSON EE (1926)	3445	747	2698	116	34	82	29	
Astronomy								
GIACCONI R (1931)	2987	905	2082	66	18	48	45	AB
GURSKY H (1930)	3258	401	2857	92	17	75	35	
OKE JB (1928)	2437	1510	927	71	34	37	34	
SALPETER EE (1924)	2441	465	1976	90	19	71	27	ABDF
SANDAGE A (1926)	3997	3309	688	90	65	25	44	A
Astrophysics								
BAHCALL JN (1934)	2569	2244	325	125	99	26	20	AB
BAME SJ (1924)	3022	474	2548	125	23	102	24	
CAMERON AGW (1925)	2628	970	1658	93	35	58	28	ABN
DALGARNO A (1928)	4127	1760	2367	180	62	118	22	BC
IBEN I (1931)	2489	2154	335	62	45	17	40	
MORTON DC (1933)	2701	1486	1215	70	41	29	38	
OSTRIKER JP (1937)	2469	1117	1352	68	30	38	36	AB
Geophysics								
FEHSENFELD FC (1934)	3682	1654	2028	129	58	71	28	
LE PICHON X (1937)	2488	1303	1185	49	26	23	50	U
Physics								
ABRAMS GS (1941)	3249	634	2615	55	14	41	59	
ADLER SL (1939)	3243	3243		62	62		52	AB
ANDERSON PW (1923)*	2795	1545	1250	72	43	29	38	A
BARGER VD (1938)	2913	2873	40	120	117	3	24	
BJORKEN JD (1934)	3199	2847	352	36	30	6	88	AB
BLOEMBERGEN N (1920)*	2438	602	1836	84	25	59	29	ABYI
BOYARSKI AM (1935)	3359	490	2869	51	14	37	65	
BREIDENBACH M (1943)	3789	219	3570	51	5	46	74	
BROWN GE (1926)	2957	1062	1895	111	50	61	26	ABR
BULOS F (1925)	3008	183	2825	38	6	32	79	
CARDONA M (1936)	3190	1061	2129	166	29	137	19	
CHINOWSKY W (1929)	2993	104	2889	41	4	37	73	
COHEN ML (1935)	3882	951	2931	196	36	160	19	A
COWLEY RA (1939)	2888	1127	1761	133	37	96	21	C
CROMER DT (1923)	8778	8121	657	53	27	26	165	

Physics (cont.)	A	B	C	D	E	F	G	H
RICHTER B (1931) *	3731	54	3677	97	21	76	38	A
RUBBIA C (1934)	2890	32	2858	73	3	70	39	
SAH CT (1932)	2583	919	1664	128	41	87	20	
SATCHLER GR (1926)	3103	1155	1948	89	33	56	34	
SCHMELTEKOPF AL (1932)	2530	378	2152	69	7	62	36	
SCHWITTERS RF (1944)	2938	54	2884	38	5	33	77	
SHIRANE G (1924)	4124	793	3331	178	21	157	23	
SPICER WE (1929)	3433	327	3106	194	19	175	17	
STEWART RF (1936)	5611	4416	1195	68	47	21	82	
TRILLING GH (1930)	3773	39	3734	79	4	75	47	
VAN UITERT LG (1922)	2460	658	1802	161	34	127	15	
VANNUCCI F (1944)	2906	22	2884	35	1	34	83	
VENEZIANO G (1942)	2985	1358	1627	59	13	46	50	
WABER JT (1920)	3566	122	3444	29	5	24	122	
WEINBERG S (1933) *	7687	5711	1976	83	54	29	92	ABC
WHITAKER JS (1948)	2874	24	2850	29	1	28	99	
WILSON KG (1936)	3061	2648	413	47	25	22	65	A
ZUMINO B (1923)	2500	65	2435	35	6	29	71	
Chemical Physics								
FLYGARE WH (1936)	2790	627	2163	146	21	125	19	AB
SHULMAN RG (1924)	3551	720	2831	111	23	88	31	A
Physical Chemistry								
BENSON SW (1918)	3334	1627	1707	118	35	83	28	A
BERNSTEIN RB (1923)	3030	591	2439	118	22	96	25	AB
DAVIDSON ER (1936)	5123	314	4809	82	22	60	62	
DUBOIS JE (1920)	2798	1923	875	288	174	114	9	
DURIG JR (1935)	3136	2561	575	259	206	53	12	
FLORY PJ (1910) *	5087	1406	3681	129	46	83	39	ABD
GORDON RG (1940)	3087	1959	1128	76	33	43	40	AB
GRANT DM (1931)	4248	569	3679	106	10	96	40	
HAMILTON WC (1931)	3815	2091	1724	97	28	69	39	
HAYON E (1932)	2523	696	1827	116	26	90	21	
KARPLUS M (1930)	3777	554	3223	110	10	100	34	AB
LEHN J (1939)	2568	854	1714	118	47	71	21	AB

Physics (cont.)	A	B	C	D	E	F	G	H
DRELL SD (1926)	2748	2141	607	41	29	12	67	AB
DUKE CB (1938)	2965	1588	1377	131	73	58	22	
EASTMAN DE (1940)	2891	1596	1295	85	40	45	34	
FELDMAN GJ (1942)	3452	208	3244	63	6	57	54	
FISHER ME (1931)	4604	3085	1519	102	54	48	45	BC
FRIEDBERG CE	2964		2964	33		33	89	
FRYBERGER D (1931)	2851	17	2834	41	3	38	69	
GARITO AF (1939)	2935	228	2707	94	4	90	31	
GIACOMELLI GA (1931)	2483	234	2249	89	22	67	27	
GLASHOW SL (1932) *	3539	1818	1721	41	13	28	86	AB
GOLDHABER G (1924)	3955	446	3509	98	11	87	40	A
GREINER W (1935)	3299	95	3204	162	3	159	20	
GROSS DJ (1941)	2964	2028	936	51	31	20	58	
HANSEN O (1934)	2439	315	2124	132	23	109	18	
HANSON G (1947)	3242	70	3172	56	4	52	57	
HARARI H (1940)	2492	2014	478	52	40	12	47	b
HEEGER AJ (1936)	3450	143	3307	125	6	119	27	
JACKIW R (1939)	2932	1332	1600	60	36	24	48	B
JEAN-MARIE B (1940)	2445	28	2417	32	1	31	76	
JORTNER J (1933)	5449	622	4827	199	20	179	27	b
KADYK JA (1929)	3400	41	3359	57	4	53	59	
LARSEN RR (1929)	3111	16	3095	44	3	41	70	
LEE BW (1935)	3529	1667	1862	86	39	47	41	
LEE TD (1926) *	2868	1859	1009	62	40	22	46	A
LUTH V (1943)	3084	58	3026	47	3	44	65	
LYNCH HL (1939)	2742	51	2691	45	2	43	60	
MANN JB (1923)	2528	290	2238	37	10	27	68	
MAYER JW (1930)	2576	444	2132	149	24	125	17	
MILLER WH (1941)	2889	1676	1213	137	64	73	21	
MOORE CB (1939)	2719	758	1961	125	27	98	21	
MOREHOUSE CC (1942)	2944	23	2921	36	2	34	81	
MOTT NF (1905) *	3128	2348	780	58	43	15	53	ABCM
NESS NF (1933)	2443	1118	1325	92	37	55	26	
PATERSON JM (1937)	3117	6	3111	48	4	44	64	
PERL ML (1927)	3533	527	3006	79	10	69	44	A
PETERLIN A (1908)	3073	1556	1517	162	78	84	18	In
PHILLIPS JC (1933)	2763	1866	897	147	97	50	18	A
PHILLIPS RJ (1930)	2627	772	1855	131	35	96	20	
REEDER DD (1935)	2477	72	2405	60	2	58	41	
REMEIKA JP (1924)	2475	104	2371	154	6	148	16	

Physical Chemistry (cont.)	A	B	C	D	E	F	G	H
LIPSCOMB WN (1919) *	4420	548	3872	179	17	162	24	ABf
MARCUS RA (1923)	2525	1811	714	79	36	43	31	AB
MORINO Y (1908)	2772	1143	1629	104	41	63	26	
POLANYI JC (1929)	2831	816	2015	71	19	52	39	ABCN
RICE SA (1932)	3622	198	3424	177	13	164	20	ABR
SCHERAGA HA (1921)	8062	204	7858	297	12	285	27	AB
SCHMID H (1917)	2674	18	2656	241	5	236	11	F
SHIRLEY DA (1934)	4278	887	3391	177	29	148	24	A
SZWARC M (1909)	2593	173	2420	129	12	117	20	C
WINSTEIN S (1912)	3146	712	2434	93	10	83	33	A
Inorganic Chemistry								
ALLEN LC (1926)	2821	405	2416	66	20	46	42	
CHATT J (1914)	2665	2092	573	145	110	35	18	Cj
CHURCHILL MR (1940)	3633	3164	469	170	149	21	21	
CLARK RJH (1935)	2505	2101	404	108	84	24	23	
COLLMAN JP (1932)	3198	2766	432	82	63	19	39	AB
COTTON FA (1930)	9346	6790	2556	364	256	108	25	ABRx
DAHL LF (1929)	3440	238	3202	108	5	103	31	
DRAGO RS (1928)	3402	690	2712	142	29	113	23	
GRAY HB (1935)	4627	299	4328	192	12	180	24	ABR
GREEN M (1934)	2620	878	1742	191	64	127	13	
GUGGENHEIM HJ (1923)	2673	53	2620	167	3	164	16	
HALPERN J (1925)	2672	1139	1533	119	51	68	22	BC
HAWTHORNE MF (1928)	2748	768	1980	154	30	124	17	AB
HOFFMANN R (1937) *	7340	4170	3170	143	55	88	51	AB
HOLM RH (1934)	2954	324	2630	111	9	102	26	AB
IBERS JA (1930)	7575	208	7367	221	13	208	34	
LEWIS J (1928)	5141	1204	3937	330	60	270	15	C
MASON R (1930)	3750	1103	2647	191	61	130	19	C
MCELROY MB (1939)	2736	1027	1709	89	33	56	30	B
MUETTERTIES EL (1927)	3789	2151	1638	118	56	62	32	AB
MULLER A (1938)	3508	2088	1420	326	193	133	10	
OSBORN JA (1939)	2557	795	1762	45	5	40	56	
PEARSON RG (1919)	2901	2142	759	83	48	35	34	A
SCHRAUZER GN (1932)	2663	2389	274	112	88	24	23	
SHAW BL (1930)	3646	300	3346	159	18	141	22	C
SYMONS MCR (1925)	4593	858	3735	396	94	302	11	
TAUBE H (1915)	2802	158	2644	124	6	118	22	AB
WILLIAMS RJ (1926)	2948	245	2703	200	8	192	14	Cj

Organic Chemistry	A	B	C	D	E	F	G	H
ALLINGER NL (1928)	3023	2594	429	116	87	29	26	
BAKER BR (1915)	2657	2559	98	191	184	7	13	
BARTON DHR (1918) *	3177	2646	531	255	196	59	12	ABCM
BATTERSBY AR (1925)	2564	2290	274	134	119	15	19	CF
BENDER ML (1924)	3118	1512	1606	115	34	81	27	A
BOHLMANN F (1921)	2640	2360	280	412	369	43	6	
BOWIE JH (1938)	2627	2036	591	154	110	44	17	
BROWN HC (1912) *	8756	6723	2033	393	271	122	22	ABCZ
BRUICE TC (1925)	2876	805	2071	160	37	123	17	AB
COREY EJ (1928)	9152	8662	490	273	248	25	33	AB
CRAM DJ (1919)	2849	733	2116	137	22	115	20	AB
DJERASSI C (1923)	7704	850	6854	378	32	346	20	ABEM
ELIEL EL (1921)	2981	2313	668	94	67	27	31	A
FOLKERS K (1906)	2999	283	2716	203	17	186	14	A
GASSMAN PG (1935)	2997	2954	43	159	156	3	18	
HAMMOND GS (1921)	2858	94	2764	106	13	93	26	AKY
HANSCH C (1918)	3926	2289	1637	110	60	50	35	
HEILBRONNER E (1921)	3156	765	2391	145	40	105	21	BX
HOUSE HO (1929)	2914	2626	288	88	83	5	33	
HUISGEN R (1920)	5087	3716	1371	203	126	77	25	BFWk
INGOLD KU (1929)	2619	124	2495	132	6	126	19	CN
JENCKS WP (1927)	3527	836	2691	110	19	91	32	AB
JERINA DM (1940)	5033	1235	3798	155	21	134	32	
JOHNSON BFG (1938)	3045	1360	1685	204	84	120	14	
KATRITZKY AR (1928)	4385	1043	3342	360	82	278	12	C
KHORANA HG (1922) *	4409	311	4098	131	8	123	33	ABCM
KUPCHAN SM (1922)	2997	2681	316	173	152	21	17	
MISLOW K (1923)	3202	334	2868	154	11	143	20	AB
NAKANISHI K (1925)	2593	322	2271	213	18	195	12	B
NETA P (1938)	2460	870	1590	74	37	37	33	
NOZAKI H (1922)	2680	999	1681	245	61	184	10	
OLAH GA (1927)	7910	7190	720	403	362	41	19	A
PAQUETTE LA (1934)	5116	4493	623	345	283	62	14	
RAMIREZ F (1923)	2999	1882	1117	144	98	46	20	
ROBERTS JD (1918)	5941	92	5849	201	6	195	29	ABD
ROBINS RK (1926)	4157	64	4093	241	3	238	17	
SCHLEYER PVR (1930)	5736	1281	4455	189	28	161	30	
SORM F (1913)	4890	119	4771	382	10	372	12	ABFM

Organic Chemistry (cont.)	A	B	C	D	E	F	G	H
SWEELEY CC (1930)	2851	361	2490	84	8	76	33	
TROST B (1941)	3087	2321	766	142	121	21	21	A
TURRO NJ (1938)	3101	1906	1195	143	80	63	21	A
WENKERT E (1925)	2637	1369	1268	142	71	71	18	K
WHITESIDES GM (1939)	2625	1697	928	79	41	38	33	AB
WIBERG KB (1927)	2769	2582	187	106	95	11	26	A
WILLIAMS DH (1937)	5591	1107	4484	203	38	165	27	
WITKOP B (1917)	3921	82	3839	169	6	163	23	AF
WOODWARD RB (1917) *	3644	2360	1284	49	23	26	74	ABCM
YAGI H (1939)	2841	291	2550	147	16	131	19	
ZIMMERMAN HE (1926)	3226	3088	138	113	111	2	28	A
Organometallic Chemistry								
CLARK HC (1929)	3026	1855	1171	139	87	52	21	N
FISCHER EO (1918) *	3472	2288	1184	250	163	87	13	BFIM
HASZELDINE RN (1925)	2684	414	2270	300	51	249	8	C
KING RB (1938)	4467	3562	905	262	211	51	17	
KOCHI JK (1928)	4084	1684	2400	164	39	125	24	
LAPPERT MF (1928)	3321	727	2594	206	58	148	16	C
SCHMIDBAUR H (1934)	2576	2023	553	197	149	48	13	
SEYFERTH D (1929)	3749	3510	239	233	215	18	16	F
STONE FGA (1925)	4013	39	3974	239	4	235	16	C
WILKINSON G (1921) *	5444	58	5386	167	8	159	32	ABCR
Analytical Chemistry								
BEROZA M (1917)	2474	807	1667	168	40	128	14	
COOKS RG (1941)	2594	673	1921	143	34	109	18	
MCLAFFERTY FW (1923)	3018	1087	1931	117	32	85	25	
WEST TS (1927)	3214	257	2957	222	11	211	14	S
WINEFORDNER JD (1931)	2811	334	2477	212	22	190	13	
Theoretical Chemistry								
CLEMENTI E (1931)	4001	3011	990	76	34	42	52	
DEWAR MJS (1918)	8368	5578	2790	255	191	64	32	BC
HEHRE WJ (1945)	4856	2352	2504	85	34	51	57	
LEVINE RD (1938)	2676	1075	1601	128	47	81	20	
POPLE JA (1925)	12714	6351	6363	131	25	106	97	ABC
SCHAEFER HF (1944)	3166	697	2469	146	23	123	21	
SEGAL GA (1934)	4159	258	3901	24	7	17	173	
SIMPSON WT (1920)	4316	13	4303	25	4	21	172	
STEPHENS FS (1931)	2789	1094	1695	120	38	82	23	

Table 2: Authors on 1,000 most-cited list who are members of more than four academies.

Anfinsen C B (5) ABDRb
Barton D H R (8) ABCDLRSp
Brenner S (5) ABCDF
Caspersson T (11) BCDFJKTYhlq
Chance B (7) ABDFGWl
De Duve C (6) ABFJUi
Djerassi C (7) ABEFKel
Fisher E O (5) BFIWX
Jacob F (7) ABCDERU
Katchalski-Katzir E (6) ABCDFb
Katz B (5) ABCRc
Khorana H G (7) ABCDFYr
Krebs H A (7) ABCDFWX
Lipmann F (5) ACDFR
Mott N F (5) ABCFX
Ochoa S (10) ABCDFZhikr
Palade G E (7) ABEFJis
Perutz M F (9) ABCDFISUf
Sorm F (10) ABFLPRhprs
Woodward R B (12) ABCDFIYZacnr

contributors to the mathematical and physical, geological, and biological sciences. Twenty-four APS members are on the list.

Thirty-nine authors belong to the Deutsche Akademie der Naturforscher Leopoldina. The academies in the states of Bavaria and Göttingen have four and five members, respectively, while Heidelberg has one member listed. There are in fact 45 different academies listed.

When we did our study of the 300 most-cited authors 1961–1976, 26 Nobelists were identified.[3] Seven more on that list have since won the prize, including three of this year's winners.[1] By comparison, there are only 22 Nobelists among the top 300 in our new list of 1,000 names.

Three Nobelists on the earlier list of 300 do not appear on the new 1,000 author list. This emphasizes the chronological "bias" in these studies. Since much of the work involved in past Nobel prizes was published prior to 1965, it is remarkable that so many names remain. Thus, work *of Nobel class* generally has long-lived impact.[4]

In case you are wondering why some relatively contemporary Nobelists do not appear on this list, keep in mind that a Nobel prize is the recognition of a field as much as an accolade to particular individuals. Some fields are recognized in which there are relatively small numbers

Table 3: The academies of the 1,000 authors, including the number of authors from each academy.

A	=	National Academy of Sciences, US	240
B	=	American Academy of Arts and Sciences	191
C	=	Royal Society of London, UK	74
D	=	American Philosophical Society	24
E	=	Institute of Medicine, US	31
F	=	Deutsche Akademie der Naturforscher Leopoldina, DDR	39
G	=	National Academy of Sciences of Argentina	4
H	=	Australian Academy of Science	7
I	=	Austrian Academy of Sciences	5
J	=	Royal Academy of Sciences, Letters and Fine Arts of Belgium	7
K	=	Brazilian Academy of Sciences	5
L	=	Bulgarian Academy of Science	4
M	=	More than four academy memberships (see Table 2)	20
N	=	Royal Society of Canada	14
O	=	Academy of Sciences of Chile	1
P	=	Czechoslovakian Academy of Sciences	2
R	=	Royal Danish Academy of Sciences and Letters	16
S	=	Royal Society of Edinburgh, UK	8
T	=	Academy of Finland	2
U	=	Academy of Sciences of France	10
V	=	Academie Francaise	1
W	=	Bavarian Academy of Sciences, FRG	4
X	=	Göttingen Academy, FRG	5
Y	=	Indian Academy of Sciences, Bangalore	5
Z	=	Indian National Science Academy, New Delhi	4
a	=	Royal Irish Academy	2
b	=	Israel Academy of Sciences and Humanities	6
c	=	Lincei National Academy, Italy	4
d	=	Japan Academy	2
e	=	National Academy of Sciences of Mexico	1
f	=	Royal Netherlands Academy of Sciences and Letters	7
g	=	Norwegian Academy of Science and Letters	1
h	=	Polish Academy of Sciences	4
i	=	Pontifical Academy of Sciences	6
j	=	Lisbon Academy of Sciences, Portugal	2
k	=	Royal Spanish Academy	2
l	=	Royal Swedish Academy of Sciences	14
m	=	Academia Sinica, Taiwan	1
n	=	Slovene Academy of Arts and Sciences, Yugoslavia	2
o	=	Serbian Academy of Sciences and Arts, Yugoslavia	1
p	=	Hungarian Academy of Sciences	2
q	=	Academy of Sciences of Venezuela	1
r	=	Academy of Sciences of the USSR	4
s	=	Academy of the Socialist Republic of Romania	2
t	=	Heidelberg Academy of Sciences, FRG	1
u	=	Yugoslav Academy of Sciences and Arts	1

Classification of Authors' Research Specialties

The contention of sociologist Warren O. Hagstrom, University of Wisconsin at Madison, that "resistance to classification is quite general among scientists"[1] became clear to us while working on this project.

After we sent reprints of the first essay in this series to the 1,000 authors, we heard from several that they wished to be reclassified.

Our questionnaire was probably at fault in most instances of misclassification. We asked authors to pick from a list of 30 general disciplinary areas. Many questionnaires were returned with a single category chosen, but others came back with up to five disciplines checked. In these cases, our research staff had to choose one—based on information in directories such as *American Men and Women of Science*[2] and on the journals in which these authors published. Sometimes this led to a choice not preferred by the author.

The questionnaire also erred in not offering enough disciplinary areas. For instance, we did not include analytical chemistry. This led to a dilemma for analytical chemists who thought they had to choose another category. Fred W. McLafferty, Cornell University, an analytical chemist who was misclassified on the list, was mentioned by name in a *Chemical & Engineering News* article on the study.[3] He wrote to tell us that he has taken a bit of kidding over his classification as an organic chemist. He told us, "It seems [the organic chemists] don't want me."[4] He and four others have been reclassified as analytical chemists. The others are M. Beroza, R. G. Cooks, T. S. West, and J. D. Winefordner.

Other authors on the list who have been reclassified are: L. F. Dahl, from physical chemistry to inorganic chemistry; M. J. S. Dewar, from physical chemistry to theoretical chemistry; J. R. Durig, from inorganic chemistry to physical chemistry; R. D. Levine, from physics to theoretical chemistry; A. Muller, from physics to inorganic chemistry; P. V. R. Schleyer, from physical chemistry to organic chemistry; and G. A. Segal, from physics to theoretical chemistry.

In general, we have only changed categories at the author's request. In the cases in which one author has written to criticize another's classification, we checked our files, and if the scientist involved has clearly indicated a discipline and has *not* asked to be moved, we made no changes.

In one case, an author was so vehement in his denunciation of our misclassifying a colleague that we called the scientist in question. It turned out that he had simply checked off the wrong discipline when he filled out the questionnaire.

Despite this explanation, the "misclassification" problem is not a large one. We have heard from nearly 300 of the 1,000 authors on the list, and less than 25 presented problems.

We have learned from this exercise that we must refine our survey techniques in the future—perhaps by listing more categories or by asking an open-ended question like, "What kind of scientist are you, anyway?"

REFERENCES

1. **Hagstrom W O.** Sources of resistance among scientists to their classification on the basis of speciality. *4S Newsletter* (Society for Social Studies of Science) 2(2):15–6, 1977.
2. **Jaques Cattell Press,** ed. *American men and women of science.* New York: Bowker, 1979. 8 vols.
3. **Stinson S C.** Chemists a fourth of most-cited scientists. *Chem. Eng. News* 59(42):30–3, 1981.
4. **McLafferty F W.** Personal communication. 22 October 1981.

of researchers. So when the prize was given to A.A. Penzias and R.W. Wilson for their work in radio astronomy it was not surprising that they did not appear in a list dominated by life scientists.[4] However, when we examined the citation record for the cluster of authors turning up in the research front for radio astronomy, they were among the five most-cited authors.

As I've stated before, different fields or disciplines have different citation and publication patterns. Some of the data presented here indicate some of these differences, though I would not want to make any claims for the statistical validity where small samples for a field are represented.

Do not attribute special significance to trivial differences in citation counts of

the individual authors listed. Some authors may be associated with highly cited methods not regarded as significant breakthroughs but almost all are *of Nobel class.*[4] Keep in mind that even a list of 1,000 authors only accounts for .2 percent of publishing scientists in the world.[5] Therefore, we have most likely quite arbitrarily excluded an even larger number of equally important scientists. I'm sure that most members of the various academies would agree that there are at least an equal number of highly qualified scientists who are excluded from membership in national academies.

In the list of authors in the physical and chemical sciences (see Table 1), authors are listed alphabetically beneath their disciplines. To accurately depict their disciplines, the authors themselves were asked to name the categories they preferred. (See accompanying box for further explanation.) For each author the following information is provided—citations received, citations as a first author, citations as a subsequent author, total number of papers cited, papers as a primary author, papers as a secondary author, and citation rate.

A citation "rate" is the average number of citations per cited paper. For example, M. L. Cohen's 196 papers received 3,882 citations. The rate of citation is 19. On the other hand, J. S. Whitaker received 2,874 citations. Only 29 of his papers were involved, giving a citation rate of 99. The significance of this number varies considerably, especially when one or two highly cited papers account for most of the citations.

Academy memberships are noted by a code at the end of each entry. The codes are explained in detail in Table 3. Nobelists are indicated by asterisks.

This essay covers data for authors in the fields of aeronomy (a branch of geophysics that deals with the atmosphere of Earth and other celestial bodies), astronomy, astrophysics, geophysics, physics, chemical physics, physical chemistry, inorganic chemistry, organic chemistry, organometallic chemistry, analytical chemistry, and theoretical chemistry.

As you can see from Table 4, the average number of citations varies among disciplines. Theoretical chemistry received the highest average number of citations while analytical chemistry received the lowest. The average number of cited papers also differs among fields. For example, authors in organometallic chemistry published cited articles more often than did authors in other fields. Astronomers on the list published cited articles less often than their peers in other disciplines, averaging 82 cited papers during this time period. Harriet Zuckerman points out that this "low" is still an astonishingly high rate of cited work.[6] Publishing practices also varied. In one field, astrophysics, authors received slightly more citations as first authors than they did as secondary authors. In every other field, authors were more often cited as secondary authors. Of course, whether or not an author is cited more often as a first author could be the result of alphabetic listing popular in some journals and fields.

The organometallic chemists, physical chemists, and organic chemists were the oldest among the physical and chemical scientists. The geophysicists and the physicists were the youngest. We also observed that the average age of academy members on the list of 1,000 was 58, while the average age of all authors on the list of 1,000 was 53, and the average age of non-academy members was 51. More than half of the organic chemists (who were older than average) belonged to academies, while only about a quarter of the physicists (who were much younger) were academy members.

Sidney Drell, Stanford Linear Accelerator Center, observes that 23 of the authors on the physics portion of the list all worked together on a "fantastically important and successful collaboration"[7] at the center's electron-positron

Table 4: Discipline averages for authors in physical and chemical sciences. A = number of authors on list. B = average number of citations received. C = average primary citations. D = average secondary citations. E = average number of cited papers. F = average papers as first author. G = average papers as secondary author. H = number of authors with academy memberships. I = number of Nobelists. J = average birth year.

Discipline Name	A	B	C	D	E	F	G	H	I	J
Aeronomy	2	2990	929	2061	149	51	98	—	—	1928
Astronomy	5	3024	1318	1706	82	31	51	3	—	1928
Astrophysics	7	2858	1458	1400	103	48	55	4	—	1930
Geophysics	2	3085	1478	1606	89	42	47	1	—	1935
Physics	73	3254	1056	2198	85	25	60	22	7	1935
Chemical physics	2	3170	673	2497	128	22	106	2	—	1930
Physical chemistry	22	3611	984	2627	144	39	105	15	2	1925
Inorganic chemistry	28	3759	1448	2311	166	58	108	16	1	1929
Organic chemistry	49	3838	1861	1977	185	85	100	30	4	1926
Organometallic chemistry	10	3684	1616	2068	216	98	117	7	2	1927
Theoretical chemistry	9	5227	2270	2957	110	45	65	2	—	1932
Analytical chemistry	5	2822	631	2191	172	28	144	1	—	1928

storage ring. That collaboration resulted in a 1974 paper published in *Physical Review Letters* entitled "Discovery of a narrow resonance in e^+ e^- annihilation."[8] One of the authors listed on that paper, B. Richter, won his Nobel prize for work in this area. He and G. Goldhaber, another author on that paper, both have published more papers than the other collaborators. Interestingly, ten of those 23 authors who made the top 1,000 would not have appeared on the list were it not for the 626 citations which that single paper received.

This example illustrates the difficulties in assigning credit to multiauthored works. Some would agree with Derek J. de Solla Price, who argues that it is absurd to give all authors on a large team equal credit to that received by someone who is sole author of a highly cited paper. In a letter to *Science*,[9] Price suggested that perhaps credit should be assigned *proportionately* to each author, that is, a citation to a paper with two authors means that both receive credit for one-half of a citation. Three authors of a single paper would receive credit for one-third of all citations to that paper, and so on. Had we used this method of counting, one-quarter of the physicists in this study would not have made the list. A similar drop-off might occur for other fields also, but this is more properly a subject for future essays. Our main purpose was to eliminate the shortcomings of studies based on first-authorship only.

Since we had to limit the size of this study we have not been able to list the many other prestigious awards received by these authors. We intend to do this in a separate study of the "unNobel prizes." Not the least of these are the various National Medal of Science winners such as astronomer A. R. Sandage and physical chemist Saul Winstein.

Clearly it would have been interesting to study the educational origins of this group, perhaps to determine how many were taught by other Nobelists or to determine which educational institutions produced these productive scientists.

I've often been asked why we gather data on prizes won by highly cited authors. There can be no doubt that there is something defensive about this activity. There is great controversy about the use of citation or publication counting in evaluating scientists. The whole process of so-called peer review or evaluation is a very sensitive issue. Can anyone ever put a number on the worth of scientific discovery? There are those who reasonably argue that trying to measure the significance of individual scientific work is

as impossible as measuring beauty. It is an inherently subjective process. As long as we recognize that the procedures in electing people to academies are inherently subjective and political, we need not kid ourselves that the procedures involved are infallible. I cannot stress too often that citation analysis is a measure of impact in the literature and an imperfect one at that. But the size of the scientific enterprise is so large that we need better and more objective indicators of merit at those times when we wish to exercise collective subjective judgments. That's what a committee does.

I wish we could afford the time and space to discuss the achievements of each scientist identified in this study. That is ultimately the purpose of our *Atlas of Science*[10] or our *Citation Classics* series.[11] We didn't even have the space to mention the fields they have pioneered, most of which turn up in the continuing series of research fronts we publish for use with our new online facilities.[12,13]

In the next part of this series, I will begin a discussion of authors in the life sciences including biochemistry, molecular biology, biophysics, cell biology, enzymology, genetics, and plant sciences.

* * * * *

My thanks to Dorothy Silver and Esther Surden for their help in the preparation of this essay.

REFERENCES

1. **Garfield E.** The 1,000 contemporary scientists most-cited 1965–1978. Part 1. The basic list and introduction. *Current Contents* (41):5–14, 12 October 1981.
2. **Merton R K.** The Matthew effect in science. *Science* 159:56–63, 1968.
3. **Garfield E.** The 300 most-cited authors, 1961–1976, including co-authors at last. 1. How the names were selected. *Current Contents* (28):5–17, 10 July 1978.*
4. ----------. Are the 1979 prizewinners *of Nobel class*? *Current Contents* (38):5–13, 22 September 1980.*
5. **Price D J D.** The citation cycle. (Griffith B C, ed.) *Key papers in information science.* White Plains, NY: Knowledge Industry Publications, 1980. p. 195–210.*
6. **Zuckerman H.** Personal communication. 23 December 1981.
7. **Drell S D.** Personal communication. 25 November 1981.
8. **Augustin J E, Boyarski A M, Breidenbach M, Bulos F, Dakin J T, Feldman G J, Fischer G E, Fryberger D, Hanson G, Jean-Marie B, Larsen R R, Lüth V, Lynch H L, Lyon D, Morehouse C C, Paterson J M, Perl M L, Richter B, Rapidis P, Schwitters R F, Tanenbaum W M, Vannucci F, Abrams G S, Briggs D, Chinowsky W, Friedberg C E, Goldhaber G, Hollebeek R J, Kadyk J A, Lulu B, Pierre F, Trilling G H, Whitaker J S, Wiss J & Zipse J E.** Discovery of a narrow resonance in $e^+ e^-$ annihilation. *Phys. Rev. Lett.* 33:1406–8, 1974.
9. **Price D J D.** Letter to the editor. (Multiple authorship.) *Science* 212:986, 1981.
10. **Garfield E.** Introducing the *ISI Atlas of Science: Biochemistry and Molecular Biology, 1978/80. Current Contents* (42):5–13, 19 October 1981.
11. ----------. *Citation Classics*—four years of the human side of science. *Current Contents* (22):5–16, 1 June 1981.
12. **Institute for Scientific Information.** *Index to research fronts in ISI/BIOMED™.* Philadelphia: ISI, 1981. 205 p.
13. ----------. *Index to research fronts in ISI/CompuMath™.* Philadelphia: ISI, 1981. 261 p.

*Reprinted in: **Garfield E.** *Essays of an information scientist.* Philadelphia: ISI Press, 1981. 4 vols.