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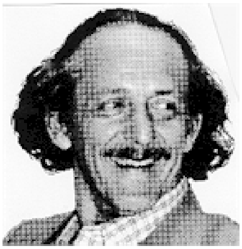

Current Comments

The 1,000 Most-Cited Contemporary Authors. Part 2B. Details on Authors in Biochemistry, Biophysics, Cell Biology, Enzymology, Genetics, Molecular Biology, and Plant Sciences

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In this essay, we continue our study of the 1,000 most-cited contemporary scientists. In Part 1 we provided the entire list of authors.[1] Part 2A examined data for 214 authors in the physical and chemical sciences.[2] This essay covers 267 authors in the first of three groups of life sciences disciplines. The remaining life scientists will be covered in two more essays to follow. The next part will cover immunology, virology, microbiology, physiology, histology, and hematology. The final part will cover 14 other life and clinical sciences disciplines.

The term "contemporary authors" is used because the citation data culled for this analysis were limited to articles published from 1965 to 1978, and indexed in *Science Citation Index*® (*SCI*®). Data for cited books were not included. The list was produced from "all-author" data, meaning that each author was treated as a first author, regardless of his or her position in an article's by-line.

The disciplines included in this essay are biochemistry, biophysics, cell biology, enzymology, genetics, molecular biology, and plant sciences. Classifying scientists by traditional disciplines is a real challenge, especially in the life sciences. A recent book which defines the various branches of biology makes this clear. As Joshua Lederberg writes in the genetics section of the book: "The science of living things is too complicated both in method and in objective to yield to tidy classification."[3] He goes on to note that genetics is "a particular way of looking at almost every aspect of biology." The same can perhaps be said for many life sciences disciplines.

Another reason it is often difficult to classify scientists is that many of them work in more than one discipline. And sometimes a scientist will start in a discipline like physics and then "cross over" into molecular biology. Thus, while a particular scientist may have accumulated a massive citation record in one field, he or she may be treated in this study as part of another discipline. Quite often, scientists are ambivalent about their classifications. If a molecular biologist is using the techniques of X-ray crystallography, he or she may have divided loyalties. For example, M. Sundaralingam, University of Wisconsin, chose to be listed here as a biophysicist, but he also considers himself an X-ray crystallographer.

We allowed the authors in this study to classify themselves by checking the appropriate box in a list of specialties included in a questionnaire. Not surprisingly, we found considerable disciplinary overlap. For example, many authors checked biochemistry as well as other disciplines, sometimes as many as three or four. In cases where authors checked more than one box, we used other methods to "pigeonhole" them. Since the publication of the original list of 1,000 authors, two of the authors listed

Table 1: The most-cited scientists in the preclinical basic sciences (first group), 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 2. Asterisks indicate Nobel prizewinners.

	A	B	C	D	E	F	G	H
Biochemistry								
ALLFREY VG (1921)	4196	218	3978	73	7	66	57	
ANDREWS P (1928)	2515	2245	270	50	26	24	50	
ANFINSEN CB (1916) *	4343	288	4055	92	10	82	47	ABDM
ANTONINI E (1931)	3127	962	2165	166	29	137	18	
ATKINSON DE (1921)	3301	2341	960	44	14	30	75	
AXEN R (1930)	2573	1577	996	28	11	17	91	
BENESCH R (1919)	2870	2003	867	62	32	30	46	
BENESCH RE (1925)	2742	570	2172	43	17	26	63	
BROWN MS (1941)	3188	1430	1758	119	45	74	26	A
CANTOR CR (1942)	2616	541	2075	75	16	59	34	
CASIDA JE (1929)	2445	340	2105	149	13	136	16	
CHANCE B (1913)	7131	2756	4375	286	94	192	24	ABDM
CHRAMBACH A (1927)	2744	1321	1423	80	13	67	34	
CUATRECASAS P (1936)	10543	7060	3483	179	59	120	58	
DAWSON RMC (1924)	2477	669	1808	91	27	64	27	
DELUCA HF (1930)	12090	998	11092	323	33	290	37	AB
EDELHOCH H (1922)	2644	1359	1285	94	19	75	28	
ERNSTER L (1920)	3592	508	3084	87	10	77	41	I
ESTABROOK RW (1926)	4314	274	4040	87	13	74	49	A
EYLAR EH (1934)	3293	1002	2291	79	18	61	41	
FASMAN GD (1925)	4228	531	3697	95	14	81	44	
GELBOIN HV (1929)	4169	931	3238	93	17	76	44	
GOLDSTEIN IJ (1929)	3201	1241	1960	90	17	73	35	
GOODWIN TW (1916)	2543	171	2372	156	13	143	16	C
GROSS J (1917)	2546	17	2529	67	2	65	38	AB
HAMBERG M (1944)	4915	3579	1336	85	40	45	57	
HENDERSON JF (1933)	2605	723	1882	123	41	82	21	
HILL RL (1928)	2919	282	2637	98	6	92	29	ABE
HORECKER BL (1914)	3190	142	3048	129	9	120	24	ABK
HUISMAN THJ (1923)	3082	1314	1768	154	42	112	20	
JACKSON RL (1939)	2784	887	1897	103	46	57	27	
JOHNSON GS (1943)	2557	988	1569	43	20	23	59	
KIVIRIKKO KI (1937)	2501	1220	1281	77	19	58	32	
Biochemistry (cont.)								
TANFORD C (1921)	5924	1252	4672	91	20	71	65	AB
TAPPEL AL (1926)	4258	566	3692	134	12	122	31	
TATA JR (1930)	2837	1351	1486	67	33	34	42	C
TOMKINS GM (1926)	7252	902	6350	112	10	102	64	
UDENFRIEND S (1918)	8641	1211	7430	162	10	152	53	AB
VAGELOS PR (1929)	2933	133	2800	96	3	93	30	ABE
VALLEE BL (1919)	4829	651	4178	159	14	145	30	ABR
VAN DEENEN LL (1928)	8267	274	7993	214	10	204	38	Bf
VAUGHAN M (1926)	2572	231	2341	78	7	71	32	
WALSH DA (1939)	2490	1170	1320	37	16	21	67	
WEBER K (1936)	13427	10402	3025	137	45	92	98	
WESTPHAL OH (1913)	3129	53	3076	104	9	95	30	Ft
WILLIAMSON JR (1933)	2958	1925	1033	81	39	42	36	
WILSON DF (1938)	2713	1416	1297	115	59	56	23	
Molecular Biology								
ATTARDI G (1926)	3294	937	2357	80	12	68	41	
BARRELL BG (1944)	2898	297	2601	33	5	28	87	
BERG P (1926) *	3411	152	3259	79	11	68	43	AE
BERNARDI G (1929)	2438	1211	1227	86	26	60	28	
BORISY GG (1942)	3110	1471	1639	45	10	35	69	
BORST P (1934)	2661	879	1782	99	16	83	26	I
BRAWERMAN G (1927)	2623	636	1987	39	10	29	67	
BRENNER S (1927)	2611	539	2072	49	11	38	53	ABCM
BRITTEN RJ (1919)	4360	2348	2012	51	10	41	85	A
BROWN DD (1931)	3218	1599	1619	76	35	41	42	AB
BROWNLEE GG (1942)	2882	1355	1527	32	12	20	90	
CHALKLEY R (1939)	3742	180	3562	65	4	61	57	
CHAMBON PH (1931)	3397	767	2630	71	18	53	47	U
CLARK AJ (1933)	2853	1000	1853	65	22	43	43	
COHEN SN (1935)	2884	1226	1658	90	36	54	32	AB

Biochemistry (cont.)

	A	B	C	D	E	F	G	H
KODICEK E (1908)	2623	194	2429	71	6	65	36	C
KOSHLAND DE (1920)	5208	1124	4084	111	11	100	46	AB
KREBS EG (1918)	4578	86	4492	61	1	60	75	AB
KREBS HA (1900) *	4670	1079	3591	83	25	58	56	ABCM
LANDS WEM (1930)	2441	713	1728	72	15	57	33	
LARDY HA (1917)	5064	617	4447	128	8	120	39	ABD
LEHNINGER AL (1917)	3447	837	2610	92	15	77	37	ABDF
LEONARD NJ (1916)	3080	1004	2076	148	56	92	20	ABh
LI CH (1913)	4773	1522	3251	249	62	187	19	ABOm
LINNANE AW (1930)	2916	357	2559	78	8	70	37	CH
LIPMANN F (1899) *	3173	265	2908	56	10	46	56	ACDM
LOWRY OH (1910)	2570	439	2131	74	8	66	34	ABR
MEISTER A (1922)	3691	447	3244	163	14	149	22	ABE
MILLER EJ (1935)	3140	1915	1225	79	30	49	39	
MITCHELL PD (1920) *	3537	2913	624	60	32	28	58	ABC
MUNRO HN (1915)	4299	833	3466	145	30	115	29	AS
NORMAN AW (1938)	3432	962	2470	142	26	116	24	
OCHOA S (1905) *	2462	33	2429	61	3	58	40	ABCM
OVCHINNIKOV YA (1934)	2458	516	1942	165	34	131	14	FL
PASTAN IH (1931)	8090	1666	6424	171	34	137	47	
PIEZ KA (1924)	3067	615	2452	48	15	33	63	
PORATH JO (1921)	3349	1036	2313	58	15	43	57	I
PORTER JW (1915)	2619	168	2451	130	17	113	20	
PROCKOP DJ (1929)	5555	608	4947	136	11	125	40	
RACKER E (1913)	6206	1251	4955	143	26	117	43	AB
REICH E (1927)	2753	134	2619	76	9	67	36	
ROEDER RG (1942)	2748	1454	1294	29	8	21	94	
ROSEMAN S (1921)	4377	661	3716	92	4	88	47	AB
SAMUELSSON B (1934)	7377	996	6381	140	23	117	52	
SATO R (1923)	3388	183	3205	169	58	111	20	
SHARON N (1925)	3699	906	2793	130	16	114	28	
SJOVALL J (1928)	2814	282	2532	110	9	101	25	
SMITH EL (1911)	3812	574	3238	163	43	120	23	ABD
SNYDER F (1931)	3172	1041	2131	171	46	125	18	
SPIRO RG (1929)	3258	2350	908	54	29	25	60	
STADTMAN ER (1919)	2636	305	2331	78	7	71	33	AB
STECK TL (1939)	4457	1510	2947	38	15	23	117	
STEINBERG D (1922)	3025	652	2373	123	28	95	24	

Molecular Biology (cont.)

	A	B	C	D	E	F	G	H
DATTA N (1922)	2796	1063	1733	64	22	42	43	
DAVIDSON EH (1937)	3334	1180	2154	61	19	42	54	
DAVIDSON NR (1916)	4702	314	4388	123	17	106	38	A
DOTY PM (1920)	2762	3	2759	48	1	47	57	ABDo
FELSENFELD G (1929)	3200	460	2740	36	5	31	88	A
FLEISCHER S (1930)	2925	629	2296	64	10	54	45	
GALL JG (1928)	2465	1328	1137	39	19	20	63	AB
GOODMAN HM (1938)	2829	486	2343	81	5	76	34	
GREEN M (1926)	3554	988	2566	166	25	141	21	
GROS F (1925)	2491	29	2462	104	4	100	23	U
HARTLEY BS (1926)	3209	1104	2105	40	6	34	80	C
HURWITZ J (1928)	3297	288	3009	80	6	74	41	AB
JACOB F (1920) *	3603	340	3263	106	10	96	33	ABCM
KABACK HR (1936)	3333	1371	1962	85	20	65	39	
KLUG A (1926)	3308	522	2786	85	19	66	38	BC
KORNBERG A (1918) *	5275	445	4830	103	9	94	51	AC
KURLAND CG (1936)	2548	483	2065	44	6	38	57	
LAEMMLI UK (1940)	5148	4790	358	20	11	9	257	
LEDER P (1934)	3980	657	3323	73	17	56	54	A
LEHMANN H (1910)	3780	548	3232	284	56	228	13	C
LOENING UE (1931)	3626	3031	595	25	10	15	145	
MAIZEL JV (1934)	5596	1025	4571	53	6	47	105	
MONOD JL (1910) *	2973	2301	672	17	3	14	174	A
NEVILLE DM (1934)	3821	1192	2629	38	8	30	100	
NISHIMURA S (1931)	2638	531	2107	113	8	105	23	
NOMURA M (1927)	5174	1408	3766	121	18	103	42	ABR
PAPAHADJOPOULOS DP (1934)	3496	2135	1361	67	31	36	52	
PAUL J (1922)	3541	1228	2313	115	36	79	30	S
PENMAN S (1930)	7539	1841	5698	105	11	94	71	
PERRY RP (1931)	3577	2159	1418	69	28	41	51	A
PERUTZ MF (1914) *	4921	4003	918	61	34	27	80	ABCM
PHILLIPS DC (1924)	2481	527	1954	42	11	31	59	BC
PORTER KR (1912)	2635	446	2189	65	18	47	40	AB
RABINOWITZ M (1927)	2532	632	1900	126	28	98	20	
RICH A (1924)	4811	236	4575	166	17	149	28	ABi
RICHARDSON CC (1935)	3078	750	2328	64	6	58	48	B
RUTTER WJ (1928)	4481	330	4151	95	4	91	47	

Molecular Biology (cont.)

	A	B	C	D	E	F	G	H
SANGER F (1918) *	3194	1418	1776	29	10	19	110	ABC
SCHIMKE RT (1932)	4810	1143	3667	73	12	61	65	AB
SCHLESSINGER D (1936)	2695	352	2343	104	11	93	25	
SHARP PA (1944)	2693	1205	1488	42	10	32	64	
SIMS P (1920)	4617	1147	3470	100	24	76	46	
SINSHEIMER RL (1920)	4162	123	4039	118	7	111	35	ABE
SPIEGELMAN S (1914)	8415	953	7462	131	20	111	64	AB
STUDIER FW (1936)	4203	3467	736	23	12	11	182	
SZYBALSKI W (1921)	2890	327	2563	76	10	66	38	
VINOGRAD J (1913)	4185	824	3361	63	8	55	66	A
WEISSBACH H (1932)	3395	563	2832	154	23	131	22	
WITTMANN HG (1927)	2776	333	2443	83	15	68	33	BF
WYMAN J (1901)	4133	229	3904	71	8	63	58	ABc
YANOFSKY C (1925)	4654	627	4027	130	13	117	35	ABF
ZINDER ND (1928)	2528	162	2366	72	5	67	35	AB

Biophysics

	A	B	C	D	E	F	G	H
ALLERHAND A (1937)	2608	1565	1043	67	30	37	38	
BERNHARD W (1920)	2881	986	1895	61	17	44	47	
BLOW DM (1931)	2465	735	1730	26	10	16	94	C
BUTLER WL (1925)	2454	675	1779	85	19	66	28	AB
CHAPMAN D (1927)	4404	1442	2962	124	44	80	35	
CURRAN PF (1931)	2801	337	2464	64	9	55	43	
GREEN DE (1910)	3507	1497	2010	135	53	82	25	ABJ
KARLE IL (1921)	2872	1107	1765	103	57	46	27	A
KATCHALSKI-KATZIR E (1916)	2613	17	2596	72	2	70	36	ABCM
KATZ B (1911) *	3049	2969	80	50	41	9	60	ABCM
KEARNS DR (1935)	3695	1126	2569	124	22	102	29	
KLINGENBERG ME (1928)	2548	479	2069	73	18	55	34	
MCCONNELL HM (1927)	5697	368	5329	102	12	90	55	AB
MILEDI R (1927)	5059	1654	3405	93	30	63	54	C
PACKER L (1929)	2650	654	1996	117	34	83	22	
REYNOLDS JA (1930)	2548	1274	1274	67	29	38	38	
SETLOW RB (1921)	2879	1122	1757	75	24	51	38	AB
SHAPIRO AL (1930)	2999	2955	44	15	9	6	199	
SMALL DM (1931)	3322	1020	2302	109	21	88	30	

Cell Biology (cont.)

	A	B	C	D	E	F	G	H
KARNOVSKY MJ (1926)	11427	3199	8228	124	12	112	92	B
KIPNIS DM (1927)	5676	223	5453	109	6	103	52	ABE
KORN ED (1928)	2480	1020	1460	67	21	46	37	
LODISH HF (1941)	3517	1817	1700	90	35	55	39	
MAHLER HR (1921)	2528	421	2107	100	23	77	25	
MANDEL P (1908)	4966	311	4655	424	32	392	11	
MATHE G (1922)	3951	2544	1407	276	149	127	14	C
MEANS AR (1941)	2555	882	1673	86	24	62	29	
MELMON KL (1934)	3427	642	2785	133	21	112	25	BE
MIRSKY AE (1900)	2458	243	2215	29	6	23	84	ADF
NICOLSON GL (1943)	6047	3245	2802	77	39	38	78	
NORTHCOTE DH (1921)	2945	613	2332	91	11	80	32	C
OSBORN M (1940)	10376	501	9875	38	13	25	273	
PALADE GE (1912) *	7915	277	7638	96	5	91	82	ABEM
PARDEE AB (1921)	3110	1117	1993	70	18	52	44	ABE
POTTER VR (1911)	3754	321	3433	99	15	84	37	AB
RAFF MC (1938)	4499	2502	1997	47	22	25	95	
RASMUSSEN H (1925)	4558	2131	2427	129	35	94	35	
REESE TS (1935)	2584	634	1950	53	9	44	48	
ROSS R (1929)	4108	2642	1466	111	46	65	37	J
RUBIN H (1926)	2508	686	1822	83	27	56	30	AB
SANDBERG AA (1921)	3027	679	2348	176	28	148	17	
SIEKEVITZ P (1918)	3424	241	3183	53	9	44	64	AB
SINGER SJ (1924)	5647	2780	2867	88	13	75	64	AB
STEIN Y (1926)	2436	269	2167	88	7	81	27	
STEINER A (1936)	2885	1640	1245	54	20	34	53	
VENABLE JH (1929)	3241	2926	315	30	9	21	108	
WEISSMANN G (1930)	5372	2449	2923	154	60	94	34	
WESSELLS NK (1932)	2791	1478	1313	44	18	26	63	

Enzymology

	A	B	C	D	E	F	G	H
COON MJ (1921)	2947	100	2847	79	8	71	37	
FRIDOVICH I (1929)	5141	846	4295	107	16	91	48	AB
HAYAISHI O (1920)	3437	345	3092	142	14	128	24	ABFd
KAPLAN NO (1917)	4230	251	3979	142	5	137	29	ABk

Biophysics (cont.)	A	B	C	D	E	F	G	H
SMITH ICP (1939)	2976	273	2703	108	18	90	27	N
STOECKENIUS W (1921)	2471	479	1992	56	14	42	44	A
SUNDARALINGAM M (1931)	4022	1731	2291	111	27	84	36	
TAYLOR EW (1929)	3431	732	2699	42	7	35	81	C
TILL JE (1931)	3489	120	3369	82	8	74	42	N
TSO POP (1929)	2477	365	2112	97	10	87	25	m
URRY DW (1935)	3386	2118	1268	131	71	60	25	

Cell Biology

	A	B	C	D	E	F	G	H
ALEXANDER P (1922)	4829	1362	3467	124	45	79	38	F
BAGLIONI C (1933)	2735	556	2179	96	25	71	28	
BASERGA R (1925)	3046	855	2191	120	22	98	25	
BJORKLUND A (1945)	3549	1910	1639	105	45	60	33	
BLOBEL G (1936)	4050	2609	1441	54	16	38	75	
BORNSTEIN P (1934)	3071	1470	1601	69	23	46	44	
BRADBURY EM (1933)	2448	1337	1111	93	40	53	26	
BRANTON D (1932)	3408	1651	1757	62	10	52	54	AB
BURGER MM (1933)	4443	2450	1993	67	15	52	66	
CASPERSSON T (1910)	2599	2548	51	33	29	4	78	BCDM
COHN ZA (1926)	4162	1426	2736	75	13	62	55	A
COMMINGS DE (1935)	2662	2472	190	100	84	16	26	
DARNELL JE (1930)	7904	1731	6173	81	8	73	97	AB
DE DUVE C (1917) *	4663	1971	2692	43	12	31	108	ABFM
DEROBERTIS E (1913)	2639	1014	1625	76	19	57	34	G
FAIRBANKS G (1940)	3210	2803	407	17	4	13	188	
FARQUHAR MG (1928)	3512	1025	2487	44	8	36	79	
FRANKE WW (1940)	3031	1545	1486	127	55	72	23	
FUXE K (1938)	13319	2548	10771	238	63	175	55	I
GALLO RC (1937)	4140	1023	3117	144	42	102	28	
GREEN H (1925)	4223	739	3484	105	28	77	40	AB
GREENGARD P (1925)	8033	722	7311	119	19	100	67	AB
HARRIS H (1925)	2661	1351	1310	61	20	41	43	BC
HAYFLICK L (1928)	2824	1876	948	66	20	46	42	
HIRSCH JG (1922)	2803	484	2319	43	7	36	65	AE
HOLTZER H (1922)	3069	219	2850	80	13	67	38	
INBAR M (1939)	2577	1896	681	43	22	21	59	

Enzymology (cont.)	A	B	C	D	E	F	G	H
KAUFMAN S (1924)	2620	820	1800	131	40	91	20	
MASSEY V (1926)	3221	1166	2055	103	19	84	31	C

Genetics

	A	B	C	D	E	F	G	H
BONNER JF (1910)	7049	1144	5905	114	12	102	61	AF
CLEAVER JE (1938)	3309	2607	702	73	48	25	45	
FREDRICKSON DS (1924)	9499	5523	3976	125	23	102	75	ABE
GILLESPIE D (1940)	2709	1896	813	50	10	40	54	
GOLDSTEIN JL (1940)	3866	1777	2089	116	47	69	33	A
HARRIS H (1919)	3729	554	3175	139	24	115	26	AC
HELINSKI DR (1933)	3039	218	2821	65	6	59	46	A
HIRSCHHORN K (1926)	3070	334	2736	189	21	168	16	
HSU TC (1917)	2820	855	1965	103	38	65	27	
KELLEY WN (1939)	3528	1266	2262	114	34	80	30	
KLEIN J (1936)	3677	1055	2622	146	32	114	25	
MCKUSICK VA (1921)	2716	769	1947	139	42	97	19	A
NEBERT DW (1940)	3226	1908	1318	97	36	61	33	
NIRENBERG M (1927) *	2914	364	2550	62	3	59	47	Ai
OBRIEN JS (1934)	3721	1597	2124	90	30	60	41	
OHNO S (1928)	2702	1353	1349	147	79	68	18	AB
RUDDLE FH (1929)	3688	696	2992	172	24	148	21	AB
SHREFFLER DC (1933)	3659	780	2879	111	15	96	32	E
SIMINOVITCH L (1920)	2655	143	2512	69	5	64	38	CN
THOMAS CA (1927)	2707	359	2348	71	14	57	38	B
ZECH L (1923)	3363	349	3014	56	8	48	60	

Plant Sciences

	A	B	C	D	E	F	G	H
HAGEMAN RH (1917)	2687		2687	76		76	35	
IZAWA S (1926)	2454	903	1551	44	17	27	55	
MORRE DJ (1935)	3065	629	2436	122	27	95	25	
SKOOG F (1908)	2501	488	2013	77	6	71	32	AB
SPURR AR (1915)	2716	2455	261	20	4	16	135	
TOLBERT NE (1919)	2731	817	1914	96	8	88	28	

here, by their own request, have been reclassified—C. H. Li from pharmacology to biochemistry, and Fritz A. Lipmann from microbiology to biochemistry.

Table 1 lists the 267 authors in this group of life sciences disciplines. Their names are listed alphabetically below the appropriate discipline heading. The table contains information about each author's citations and number of cited papers. Taken all together, the authors in this section received more citations as secondary authors than as primary authors of journal articles. They also published more cited papers as secondary authors than as primary authors.

The citation rate given in column G is the average number of citations per cited paper. For example, K. Fuxe's 238 cited papers received 13,319 citations. The rate of citation is 55. On the other hand, G. Felsenfeld's 36 cited papers received 3,200 citations for a citation rate of 88.

Do not attribute special significance to small differences in individual citation counts. Keep in mind that even a list of 1,000 authors accounts for just .2 percent of regularly publishing scientists in the world. Therefore, while virtually all of the authors presented here are *of Nobel class*,[4] we have probably excluded from this study a large number of very important scientists.

Included in Table 1 is each author's year of birth. This group includes the oldest of the 1,000, Lipmann, Nobel laureate and professor of biochemistry, Rockefeller University. Lipmann was born in 1899, and coauthored his most-cited paper in this study when he was 72 years old.[5]

Since the publication of the first essay in this series in October 1981, I was saddened to hear of the death of Hans Krebs, who appears in this group of authors. In 1953, Krebs won the Nobel prize for his discovery of the citric acid cycle, now commonly known as the Krebs cycle.[6] Krebs was a member of the *SCI* editorial advisory board and inspired much of my work with continued encouragement over the years. We have also learned from Mrs. Zora Šormová that František Šorm, whose name appeared in Part 2A, died in November 1980. Šorm had been director of the Institute of Organic Chemistry and Biochemistry of the Czechoslovakian Academy of Sciences, of which he formerly served as president. He served on the editorial board of *Current Abstracts of Chemistry and Index Chemicus*®. These great scientists and humanitarians are mourned by their colleagues throughout the world.

The asterisks in Table 1 identify Nobel laureates. Along with Lipmann and Krebs, there are 13 other Nobelists in this group. Six are from molecular biology, five from biochemistry, two from cell biology, and one each from biophysics and genetics.

Fewer than half (130) of the scientists listed here are members of national academies. (The letters in column H of Table 1 denote academy memberships, while Table 2 provides a key to these letter codes.) Although the majority of scientists listed under molecular biology, biophysics, enzymology, and genetics *are* academy members, less than half of the biochemists, cell biologists, and plant scientists hold academy memberships. Thirteen authors in this group are members of more than four academies. They are listed in Table 3.

As this essay went to press, the US National Academy of Sciences (NAS) admitted 60 new members and 12 foreign associates to the academy. Of these, 17 appear in the list of 1,000 authors in Part 1. This raises the number of NAS members in this study to 257. The 17 new members will be identified in the next essay in this series.

Table 4 provides citation and authorship data for the disciplines in this

Table 2: The academies of the 1,000 authors.

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

group. The numbers are averages for the authors in each discipline. Biochemistry is most heavily represented here, with 85 authors on the list. Al Tappel, University of California, Davis, notes that the biochemists listed here represent a broad spectrum of interests, rather than just a few "hot spots."[7] Enzymology and plant sciences have just six authors each on the list.

Table 3: Authors listed in Table 1 who are members of more than four academies.

Anfinsen C B (5) ABDRb
Brenner S (5) ABCDF
Caspersson T (11) BCDFJKTYhlq
Chance B (7) ABDFGWl
de Duve C (6) ABFJUi
Jacob F (7) ABCDERU
Katchalski-Katzir E (6) ABCDFb
Katz B (5) ABCRc
Krebs H A (7) ABCDFWX
Lipmann F (5) ACDFR
Ochoa S (10) ABCDFZhikr
Palade G E (7) ABEFJis
Perutz M F (9) ABCDFISUf

The cell biologists average more citations per author, 4,175, than any other discipline in this group. Only the biochemists also averaged more than 4,000. The six enzymologists averaged more cited papers, 117, than authors in the other disciplines. The plant scientists are the oldest authors here with an average age of 62 years. When we performed our studies of botany journals,[8,9] plant biologist Jacob Levitt, Carnegie Institution, Stanford, California, provided some of the reasons plant scientists will cite biochemical papers, and why the reverse may not be true.[10] It is interesting that citation practices are reflected in the way plant scientists are represented in the academies. Incidentally, a group of six histologists, to be covered in the next part, conceivably might have been grouped with the cell biologists.

Our look at the physical and chemical scientists contained a brief discussion of some of the difficulties in assigning credit for citations to multiauthored works. In a letter to *Science*,[11] Derek J. de Solla Price 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. Price has proposed that such credit

Table 4: Discipline averages for authors in life sciences (first group). 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	A	B	C	D	E	F	G	H	I	J
Biochemistry	85	4002	1109	2893	108	22	86	38	5	1925
Biophysics	26	3204	1069	2135	84	24	60	14	1	1927
Cell Biology	56	4175	1429	2746	95	26	69	25	2	1928
Enzymology	6	3599	588	3011	117	17	100	4	0	1923
Genetics	21	3697	1216	2481	107	26	81	12	1	1929
Molecular Biology	67	3600	1019	2581	79	15	64	37	6	1928
Plant Sciences	6	2692	882	1810	72	10	62	1	0	1920

should perhaps be assigned proportionately to each author. For example, a citation to a paper with two authors means that each author receives credit for half of a citation. Three authors of a paper would receive one-third of all citations to that paper.

Using Price's method for assigning credit to multiauthored work, we found that one-quarter of the physicists on our list of 1,000 would drop off. Applying Price's method to the present group of authors, we found that 32 would not have made the list: 15 from biochemistry, five from cell biology, four each from molecular biology and genetics, and two each from biophysics and plant sciences. Interestingly enough, all of the enzymologists would remain on the list if Price's method were applied.

T. C. Hsu, Texas Medical Center, Houston, acknowledges that Price's method of assigning credit is an "improvement," but asserts that it is still unfair to whoever did the really important work.[12] Hsu recalls a case, a common one, in which a geneticist wanted to study the chromosomes of a hospital patient who died. A pathologist, as the only person authorized to perform autopsies, provided the geneticist with a tissue sample from the patient. In the resulting paper, the pathologist appeared as coauthor, although he contributed nothing to the research. Why, wonders Hsu, should the pathologist receive equal credit with the geneticist? Why indeed! It seems to me that many scientists are unwilling to deal strongly with the ethical issues of authorship.[13]

Hsu suggests that credit should perhaps be distributed like prize money in a golf tournament. The tournament winner gets the full amount of the prize, the runner-up gets half that amount, and the third-place golfer gets half the amount of the second. Similarly, the first author of a paper would get full credit for each citation, the second author would get credit for half a citation, and the third author would get credit for one-fourth. However, Hsu doesn't believe that any credit should be assigned beyond the fourth author. He again cites the case of the geneticist and the pathologist above, noting that by the time the paper was published, "the pediatricians, the endocrinologist, and other clinicians also got their names in a 7- or 8-authored article."[12]

The point of Hsu's anecdote is well taken, but there is as yet no statistical evidence that such cases affect the ranking of scientists who regularly publish work of high impact. The unnamed pathologist may be one of thousands who publish but rarely and need an occasional paper to bolster their careers at a local level. Of greater concern are those in positions of power who abuse that power to gain greater visibility. Journals should require that authors sign a statement not unlike those found in patent applications. This would cover the exact nature of the contribution made by each author.

But while some abuse their power, I believe they represent a small percentage of the scientists we have identified as prolific. Those who consistently publish work of high caliber often place themselves at the end of the by-line. It would be absurd to conclude that they contributed the least. Until professional societies establish clear and unambiguous guidelines on these matters, we cannot criticize individuals for breaking unwritten laws.

* * * * *

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