

# Current Comments<sup>®</sup>

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The Most-Cited Papers of All Time,  
SCI 1945-1988. Part 3. Another 100  
from the *Citation Classics* Hall of Fame

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The third group of 100 most-cited papers in the 1945-1988 *Science Citation Index*<sup>®</sup> is presented. Thirteen Nobel laureates are involved in 11 of these papers, bringing the total number of Nobelists for the top 300 papers to 38. The *Journal of Biological Chemistry* again is the leader with 12 papers in this study and 43 overall.

## Introduction

This essay continues our series on the highest impact articles of modern science, ranked by citations in the 1945-1988 *Science Citation Index*<sup>®</sup> (SCI<sup>®</sup>). We have previously presented the top 200 papers<sup>1,2</sup> and intend to cover the leading 1,000-1,500 eventually. The series will constitute an interesting and useful database for librarians, information specialists, editors, and publishers. For example, one could obtain from it a reasonable alternative list for the most significant journals of science. Rather than the impact of the average article cited, the number of supercited articles may give a different perspective. In a future essay, we will separately list the most-cited books from 1945 to 1988, which were purposely not covered in this series.

## The Third Group of 100 Most-Cited Papers

Table 1 presents bibliographic and citation data for another 100 papers on the list of all-time *Citation Classics*<sup>®</sup>. Thirty-five have already been described by the authors in published commentaries. They are indicated by asterisks, and the issue, year, and edition of publication in *Current Contents*<sup>®</sup> (CC<sup>®</sup>) follow the reference in parentheses.

In preparing the list, we came across a paper that had been frequently cited under

an incorrect spelling of the first author's surname. The 1982 *Gene* paper on pUC plasmids by Jeffrey Vieira and Joachim Messing, University of Minnesota, St. Paul, was cited correctly 2,212 times. But it was also cited incorrectly (misspelled) 357 times under "Viera J...." The combined citation tally of 2,569 ranks the paper at number 156, which is reflected in Table 1. It should have appeared in the second essay of this series.<sup>2</sup>

## ISI's Expert System for Information Quality Control

The Vieira/Viera problem is just one example of many kinds of errors that authors make, and editors fail to catch, in the bibliographies of their papers.<sup>3-5</sup> Every element of a reference is subject to incorrect, incomplete, or variant citation in the literature: not just authors' surnames or initials but also journal titles, volume numbers, pages, and years of publication.

ISI<sup>®</sup> has developed algorithms to minimize this noise in the SCI and to provide optimum quality control in our databases.<sup>3,4</sup> In a sense they act like expert systems, using clear rules to detect possible variants of a cited reference, define the correct version, and decide whether to unify the variants with it.

Of course, there are limits to how far any automated system can go before it risks introducing errors itself. ISI's expert system

A	B	C	D	Bibliographic Data
2,163	224	103	91	*Cunningham A J & Szenberg A. Further improvements in the plaque technique for detecting single antibody-forming cells. <i>Immunology</i> 14:599-600, 1968. (50/81/LS)
1,948	269	63	115	*Cutler S J & Ederer F. Maximum utilization of the life table method in analyzing survival. <i>J. Chronic Dis.</i> 8:699-712, 1958. (16/79/CP)
2,071	239	83	157	Dahlstrom A & Fuxe K. Evidence for the existence of monoamine-containing neurons in the central nervous system. <i>Acta Physiol. Scand.</i> 62(Supp. 232):1-55, 1964.
2,246	205	125	53	Davis R W, Simon M & Davidson N. Electron microscope heteroduplex methods for mapping regions of base sequence homology in nucleic acids. <i>Meth. Enzymology</i> 21:413-28, 1971.
1,959	265	103	185	Dunning T H. Gaussian basis functions for use in molecular calculations. I. Contraction of (9,5 <sub>p</sub> ) atomic basis sets for the first-row atoms. <i>J. Chem. Phys.</i> 53:2823-33, 1970.
1,888	286	86	73	Edelhoc H. Spectroscopic determination of tryptophan and tyrosine in proteins. <i>Biochemistry--USA</i> 6:1948-54, 1967.
2,178	219	19	75	*Edman P & Begg G. A protein sequenator. <i>Eur. J. Biochem.</i> 1:80-91, 1967. (9/84/LS)
1,910	282	112	156	*Engvall E & Perlmann P. Enzyme-linked immunosorbent assay, ELISA. III. Quantitation of specific antibodies by enzyme labeled anti-immunoglobulin in antigen-coated tubes. <i>J. Immunol.</i> 109:129-35, 1972. (12/87/LS)
2,162	225	77	142	*Fano U. Effects of configuration interaction on intensities and phase shifts. <i>Phys. Rev.</i> 124:1866-78, 1961. (27/77)
1,858	294	71	40	Farquhar M G & Palade G E. Junctional complexes in various epithelia. <i>J. Cell Biol.</i> 17:375-412, 1963.
2,210	211	368	1,198	Feinberg A P & Vogelstein B. A technique for radiolabeling DNA restriction endonuclease fragments to high specific activity. <i>Anal. Biochem.</i> 132:6-13, 1983.
1,948	268	75	112	Fletcher R & Powell M J D. A rapidly convergent descent method for minimization. <i>Comput. J.</i> 6:163-8, 1963.
1,967	263	179	286	Fraker P J & Speck J C. Protein and cell membrane iodinations with a sparingly soluble chloroamide, 1,3,4,6-tetrachloro-3a,6a-diphenylglycoluril. <i>Biochem. Biophys. Res. Commun.</i> 80:849-57, 1978.
1,922	278	80	13	*Gillespie D & Spiegelman S. A quantitative assay for DNA-RNA hybrids with DNA immobilized on a membrane. <i>J. Mol. Biol.</i> 12:829-42, 1965. (11/77)
2,129	230	194	350	*Gillis S, Ferm M M, Ou W & Smith K A. T cell growth factor: parameters of production and a quantitative microassay for activity. <i>J. Immunol.</i> 120:2027-32, 1978. (48/88/LS)
1,856	295	98	44	*Glashow S L, Iliopoulos J & Maiani L. Weak interactions with lepton-hadron symmetry. <i>Phys. Rev. D--Part. Fields</i> 2:1285-92, 1970. (20/80/PC&ES)
1,970	262	79	32	*Glynn I M & Chappell J B. A simple method for the preparation of <sup>32</sup> P-labelled adenosine triphosphate of high specific activity. <i>Biochem. J.</i> 90:147-9, 1964. (33/89/ET&AS; 33/89/LS; 33/89/PC&ES)
1,941	273	54	29	Grabar P & Williams C A. Méthode permettant l'étude conjuguée des propriétés électrophorétiques et immunochimiques d'un mélange de protéines. Application au sérum sanguin (Method permitting the combined study of the electrophoretic and immunochemical properties of a mixture of proteins. Application to blood serum). <i>Biochim. Biophys. Acta</i> 10:193-4, 1953.
2,088	238	77	88	*Gray E G & Whittaker V P. The isolation of nerve endings from brain: an electron microscopic study of cell fragments derived by homogenization and centrifugation. <i>J. Anat.</i> 96:79-87, 1962. (1/81/LS)
2,025	252	253	558	Hamill O P, Marty A, Neher E, Sakmann B & Sigworth F J. Improved patch-clamp techniques for high-resolution current recording from cells and cell-free membrane patches. <i>Pflügers Arch.--Eur. J. Physiol.</i> 391:85-100, 1981.
2,184	216	75	238	*Hamilton M. A rating scale for depression. <i>J. Neurol. Neurosurg. Psychiat.</i> 23:56-62, 1960. (33/81/CP)
2,151	228	65	86	*Hatchard C G & Parker C A. A new sensitive chemical actinometer. II. Potassium as a standard chemical actinometer. <i>Proc. Roy. Soc. London Ser. A</i> 235:518-36, 1956. (10/85/ET&AS; 10/85/PC&ES)
1,876	291	67	47	*Hayflick L & Moorhead P S. The serial cultivation of human diploid cell strains. <i>Exp. Cell Res.</i> 25:585-621, 1961. (26/78)

**Table 1: Bibliography of the third 100 most-cited papers, SCF® 1945-1988.** Papers are arranged alphabetically. A=1945-1988 citations. B=1945-1988 rank. C=average number of annual citations. D=1988 citations. An asterisk (\*) indicates that the paper was the subject of a *Citation Classic®* commentary. The issue, year, and edition of the commentary follow the bibliographic reference.

A	B	C	D	Bibliographic Data
2,229	209	51	30	*Allen R J L. The estimation of phosphorus. <i>Biochem. J.</i> 34:858-65, 1940. (39/82/LS)
1,882	287	65	67	Ames B N & Dubin D T. The role of polyamines in the neutralization of bacteriophage deoxyribonucleic acid. <i>J. Biol. Chem.</i> 235:769-75, 1960.
1,880	289	67	82	Anderson P W. Localized magnetic states in metals. <i>Phys. Rev.</i> 124:41-53, 1961.
2,258	202	51	43	Anson M L. The estimation of pepsin, trypsin, papain, and cathepsin with hemoglobin. <i>J. Gen. Physiol.</i> 22:79-89, 1938.
2,049	245	93	71	Axen R, Porath J & Ernback S. Chemical coupling of peptides and proteins to polysaccharides by means of cyanogen halides. <i>Nature</i> 214:1302-4, 1967.
1,936	276	149	196	*Bennett J M, Catovsky D, Daniel M-T, Flandrin G, Galton D A G, Gralnick H R & Sultan C. Proposals for the classification of the acute leukaemias. <i>Brit. J. Haematol.</i> 33:451-8, 1976. (47/84/LS)
1,952	267	163	255	Berk A J & Sharp P A. Sizing and mapping of early adenovirus mRNAs by gel electrophoresis of S1 endonuclease-digested hybrids. <i>Cell</i> 12:721-32, 1977.
1,938	275	388	463	Berridge M J. Inositol trisphosphate and diacylglycerol as second messengers. <i>Biochem. J.</i> 220:345-60, 1984.
2,242	206	52	61	*Bessey O A, Lowry O H & Brock M J. A method for the rapid determination of alkaline phosphatase with five cubic millimeters of serum. <i>J. Biol. Chem.</i> 164:321-9, 1946. (23/85/LS)
2,004	255	143	137	*Blobel G & Dobberstein B. Transfer of proteins across membranes. I. Presence of proteolytically processed and unprocessed nascent immunoglobulin light chains on membrane-bound ribosomes of murine myeloma. <i>J. Cell Biol.</i> 67:835-51, 1975. (11/85/LS)
2,169	221	136	171	*Bolton A E & Hunter W M. The labelling of proteins to high specific radioactivities by conjugation to a <sup>125</sup> I-containing acylating agent. <i>Biochem. J.</i> 133:529-39, 1973. (29/84/LS)
2,098	234	84	189	Bondi A. Van der Waals' volumes and radii. <i>J. Phys. Chem.</i> 68:441-51, 1964.
1,890	285	43	58	Bonsnes R W & Taussky H H. On the colorimetric determination of creatinine by the Jaffe reaction. <i>J. Biol. Chem.</i> 158:581-91, 1945.
2,032	249	53	12	Boyden S V. The adsorption of proteins on erythrocytes treated with tannic acid and subsequent hemagglutination by antiprotein sera. <i>J. Exp. Med.</i> 93:107-20, 1951.
1,947	270	56	23	*Boyer P D. Spectrophotometric study of the reaction of protein sulfhydryl groups with organic mercurials. <i>J. Amer. Chem. Soc.</i> 76:4331-7, 1954. (25/79/LS)
2,067	241	98	23	Britten R J & Kohne D E. Repeated sequences in DNA. <i>Science</i> 161:529-40, 1968.
2,154	227	80	49	Butcher R W & Sutherland E W. Adenosine 3',5'-phosphate in biological materials. 1. Purification and properties of cyclic 3',5'-nucleotide phosphodiesterase and use of this enzyme to characterize adenosine 3',5'-phosphate in human urine. <i>J. Biol. Chem.</i> 237:1244-50, 1962.
2,012	254	287	428	*Castagna M, Takai Y, Kaibuchi K, Sano K, Kikkawa U & Nishizuka Y. Direct activation of calcium-activated, phospholipid-dependent protein kinase by tumor-promoting phorbol esters. <i>J. Biol. Chem.</i> 257:7847-51, 1982. (6/88/LS)
1,839	299	115	5	Cheng Y-C & Prusoff W H. Relationship between the inhibition constant ( $K_i$ ) and the concentration of inhibitor which causes 50 per cent inhibition ( $I_{50}$ ) of an enzymatic reaction. <i>Biochem. Pharmacol.</i> 22:3009-108, 1973.
2,147	229	69	47	Clarke D H & Casals J. Techniques for hemagglutination and hemagglutination-inhibition with arthropod-borne viruses. <i>Amer. J. Trop. Med. Hyg.</i> 7:561-73, 1958.
1,845	297	77	78	Cooley J W & Tukey J W. An algorithm for the machine calculation of complex Fourier series. <i>Math. Comput.</i> 19:297-301, 1965.
2,118	231	54	16	*Coons A H & Kaplan M H. Localization of antigen in tissue cells. II. Improvements in a method for the detection of antigen by means of fluorescent antibody. <i>J. Exp. Med.</i> 91:1-13, 1950. (6/81/LS)

A	B	C	D	Bibliographic Data
1,944	272	49	21	<b>Hestrin S.</b> The reaction of acetylcholine and other carboxylic acid derivatives with hydroxylamine, and its analytical application. <i>J. Biol. Chem.</i> 180:249-61, 1949.
2,093	236	63	42	<b>Hirs C H W.</b> The oxidation of ribonuclease with performic acid. <i>J. Biol. Chem.</i> 219: 611-21, 1956.
2,063	243	52	70	<b>Hodgkin A L &amp; Katz B.</b> The effect of sodium ions on the electrical activity of the giant axon of the squid. <i>J. Physiol.</i> 108:37-77, 1949.
2,210	211	50	19	<b>Hoffman W S.</b> A rapid photoelectric method for the determination of glucose in blood and urine. <i>J. Biol. Chem.</i> 120:51-5, 1937.
1,867	293	75	133	<b>Karnovsky M J &amp; Roots L.</b> A "direct-coloring" thiocholine method for cholinesterases. <i>J. Histochem. Cytochem.</i> 12:219-21, 1964.
2,179	218	73	73	<b>Kauzmann W.</b> Some factors in the interpretation of protein denaturation. <i>Advan. Prot. Chem.</i> 14:1-63, 1959.
2,114	232	302	653	<b>Kyte J &amp; Doolittle R F.</b> A simple method for displaying the hydrophatic character of a protein. <i>J. Mol. Biol.</i> 157:105-32, 1982.
1,945	271	122	168	<b>Laemmli U K &amp; Favre M.</b> Maturation of the head of bacteriophage T4. I. DNA packaging events. <i>J. Mol. Biol.</i> 80:575-99, 1973.
1,912	280	76	72	<b>Littlefield J W.</b> Selection of hybrids from matings of fibroblasts <i>in vitro</i> and their presumed recombinants. <i>Science</i> 145:709-10, 1964.
2,239	207	102	15	<b>Loening U E.</b> The fractionation of high-molecular-weight ribonucleic acid by polyacrylamide-gel electrophoresis. <i>Biochem. J.</i> 102:251-7, 1967.
1,898	284	76	51	<b>Lowry O H, Passonneau J V, Hasselberger F X &amp; Schulz D W.</b> Effect of ischemia on known substrates and cofactors of the glycolytic pathway in brain. <i>J. Biol. Chem.</i> 239:18-30, 1964.
2,184	216	156	74	<b>Maniatis T, Jeffrey A &amp; Kleid D G.</b> Nucleotide sequence of the rightward operator of phage $\lambda$ . <i>Proc. Nat. Acad. Sci. USA</i> 72:1184-8, 1975.
2,110	233	75	55	<b>*Mans R J &amp; Novelli G D.</b> Measurement of the incorporation of radioactive amino acids into protein by a filter-paper disk method. <i>Arch. Biochem. Biophys.</i> 94:48-53, 1961. (43/85/LS)
2,068	240	77	77	<b>Marmur J &amp; Doty P.</b> Determination of the base composition of deoxyribonucleic acid from its thermal denaturation temperature. <i>J. Mol. Biol.</i> 5:109-18, 1962.
1,922	278	384	778	<b>Melton D A, Krieg P A, Rebagliati M R, Maniatis T, Zinn K &amp; Green M R.</b> Efficient <i>in vitro</i> synthesis of biologically active RNA and RNA hybridization probes from plasmids containing a bacteriophage SP6 promoter. <i>Nucl. Acid. Res.</i> 12:7035-56, 1984.
2,200	213	85	191	<b>Merrifield R B.</b> Solid phase peptide synthesis. 1. The synthesis of a tetrapeptide. <i>J. Amer. Chem. Soc.</i> 85:2149-54, 1963.
2,026	250	289	274	<b>Messing J &amp; Vieira J.</b> A new pair of M13 vectors for selecting either DNA strand of double-digest restriction fragments. <i>Gene</i> 19:269-76, 1982.
2,189	215	78	32	<b>Millonig G.</b> Advantages of a phosphate buffer for OsO <sub>4</sub> solutions in fixation. <i>J. Appl. Phys.</i> 32:1637, 1961.
2,161	226	166	88	<b>*Moncada S, Gryglewski R, Bunting S &amp; Vane J R.</b> An enzyme isolated from arteries transforms prostaglandin endoperoxides to an unstable substance that inhibits platelet aggregation. <i>Nature</i> 263:663-5, 1976. (18/84/LS)
1,838	300	71	54	<b>Moore S &amp; Stein W H.</b> Chromatographic determination of amino acids by the use of automatic recording equipment. <i>Meth. Enzymology</i> 6:819-31, 1963.
1,960	264	78	131	<b>Morrison W R &amp; Smith L M.</b> Preparation of fatty acid methyl esters and dimethylacetals from lipids with boron fluoride-methanol. <i>J. Lipid Res.</i> 5:600-8, 1964.
1,879	290	209	502	<b>Munson P J &amp; Rodbard D.</b> LIGAND: a versatile computerized approach for characterization of ligand-binding systems. <i>Anal. Biochem.</i> 107:220-39, 1980.
2,052	244	76	136	<b>*Murphy J &amp; Riley J P.</b> A modified single solution method for the determination of phosphate in natural waters. <i>Anal. Chim. Acta</i> 27:31-6, 1962. (12/86/AB&ES)
1,840	298	58	36	<b>*Nachlas M M, Tsou K-C, De Souza E, Cheng C-S &amp; Sellman A M.</b> Cytochemical demonstration of succinic dehydrogenase by the use of a new p-nitrophenyl substituted ditetrazole. <i>J. Histochem. Cytochem.</i> 5:420-36, 1957. (17/79/LS)
2,036	248	81	145	<b>*Nicholson R S &amp; Shain I.</b> Theory of stationary electrode polarography. <i>Anal. Chem.</i> 36:706-23, 1964. (6/81/PC&ES)

A	B	C	D	Bibliographic Data
1,940	274	162	216	<b>O'Farrell P Z, Goodman H M &amp; O'Farrell P H.</b> High resolution two-dimensional electrophoresis of basic as well as acidic proteins. <i>Cell</i> 12:1133-42, 1977.
1,992	260	50	71	<b>Ouchterlony O.</b> Antigen-antibody reactions in gels. <i>Acta Pathol. Microbiol. Scand.</i> 26:507-15, 1949.
1,955	266	54	29	<b>*Pariser R &amp; Parr R G.</b> A semi-empirical theory of the electronic spectra and electronic structure of complex unsaturated molecules. I. <i>J. Chem. Phys.</i> 21:466-71, 1953. (3/79/PC&ES)
1,979	261	55	29	<b>*Pariser R &amp; Parr R G.</b> A semi-empirical theory of the electronic spectra and electronic structure of complex unsaturated molecules. II. <i>J. Chem. Phys.</i> 21:767-76, 1953. (3/79/PC&ES)
1,923	277	48	6	<b>*Partridge S M.</b> Aniline hydrogen phthalate as a spraying reagent for chromatography of sugars. <i>Nature</i> 164:443, 1949. (14/79/AB&ES)
2,214	210	185	393	<b>Peterson G L.</b> A simplification of the protein assay method of Lowry <i>et al.</i> which is more generally applicable. <i>Anal. Biochem.</i> 83:346-56, 1977.
2,252	203	78	67	<b>Richardson K C, Jarett L &amp; Finke E H.</b> Embedding in epoxy resins for ultrathin sectioning in electron microscopy. <i>Stain Technol.</i> 35:313-23, 1960.
1,912	280	62	214	<b>Ropes M W, Bennett G A, Cobb S, Jacox R &amp; Jessar R A.</b> 1958 revision of diagnostic criteria for rheumatoid arthritis. <i>Bull. Rheumat. Dis.</i> 9:175-6, 1958.
2,096	235	48	12	<b>Sanger F.</b> The free amino groups of insulin. <i>Biochem. J.</i> 39:507-15, 1945.
2,167	222	127	101	<b>*Seeman P.</b> The membrane actions of anesthetics and tranquilizers. <i>Pharmacol. Rev.</i> 24:583-655, 1972. (4/83/LS)
1,908	283	53	34	<b>Seldinger S I.</b> Catheter replacement of the needle in percutaneous arteriography. <i>Acta Radiologica</i> 39:368-76, 1953.
2,174	220	81	17	<b>Sever J L.</b> Application of a microtechnique to viral serological investigations. <i>J. Immunol.</i> 88:320-9, 1962.
2,233	208	172	301	<b>Shannon R D.</b> Revised effective ionic radii and systematic studies of interatomic distances in halides and chalcogenides. <i>Acta Crystallogr. A—Cryst. Phys.</i> 32:751-67, 1976.
2,092	237	70	80	<b>*Shore P A, Burkhalter A &amp; Cohn V H.</b> A method for the fluorometric assay of histamine in tissues. <i>J. Pharmacol. Exp. Ther.</i> 127:182-6, 1959. (40/81/LS)
2,000	257	83	47	<b>*Skou J C.</b> Enzymatic basis for active transport of Na <sup>+</sup> and K <sup>+</sup> across cell membranes. <i>Physiol. Rev.</i> 45:596-617, 1965. (20/81/LS)
2,026	250	46	56	<b>Smith H W, Finkelstein N, Aliminoso L, Crawford B &amp; Graber M.</b> The renal clearances of substituted hippuric acid derivatives and other aromatic acids in dog and man. <i>J. Clin. Invest.</i> 24:388-404, 1945.
2,192	214	50	27	<b>Somogyi M.</b> A new reagent for the determination of sugars. <i>J. Biol. Chem.</i> 160:61-8, 1945.
2,165	223	49	36	<b>Somogyi M.</b> Determination of blood sugar. <i>J. Biol. Chem.</i> 160:69-73, 1945.
2,067	241	115	145	<b>Spudich J A &amp; Watt S.</b> The regulation of rabbit skeletal-muscle contraction. I. Biochemical studies of the interaction of the tropomyosin-troponin complex with actin and the proteolytic fragments of myosin. <i>J. Biol. Chem.</i> 246:4866-71, 1971.
1,870	292	117	45	<b>Studier F W.</b> Analysis of bacteriophage T7 in early RNAs and proteins on slab gels. <i>J. Mol. Biol.</i> 79:237-48, 1973.
2,001	256	63	91	<b>Svennerholm L.</b> Quantitative estimation of sialic acids. II. A colorimetric resorcinol-hydrochloric acid method. <i>Biochim. Biophys. Acta</i> 24:604-11, 1957.
1,853	296	84	73	<b>Thiéry J-P.</b> Mise en évidence des polysaccharides sur coupes fines en microscopie électronique (Demonstration of polysaccharides on thin sections by electron microscopy). <i>J. Microsc.—Paris</i> 6:987-1018, 1967.
2,249	204	70	20	<b>*Van Handel E &amp; Zilversmit D B.</b> Micromethod for the direct determination of serum triglycerides. <i>J. Lab. Clin. Med.</i> 50:152-7, 1957. (16/77)
2,024	253	49	49	<b>*Van Vleck J H.</b> The dipolar broadening of magnetic resonance lines in crystals. <i>Phys. Rev.</i> 74:1168-83, 1948. (31/79/PC&ES)
2,569	156	428	568	<b>Vieira J &amp; Messing J.</b> The pUC plasmids, an M13mp7-derived system for insertion mutagenesis and sequencing with synthetic universal primers. <i>Gene</i> 19:259-68, 1982.

A	B	C	D	Bibliographic Data
1,998	259	62	40	Wachstein M & Meisel E. Histochemistry of hepatic phosphatases at a physiologic pH. <i>Amer. J. Clin. Pathol.</i> 27:13-23, 1957.
1,999	258	59	63	Wroblewski F & LaDue J S. Lactic dehydrogenase activity in blood. <i>Proc. Soc. Exp. Biol. Med.</i> 90:210-3, 1955.
2,043	247	1,021	1,285	Wu M-K, Ashburn J R, Torng C J, Hor P H, Meng R L, Gao L, Huang Z J, Wang Y Q & Chu C W. Superconductivity at 93 K in a new mixed phase Y-Ba-Cu-O compound system at ambient pressure. <i>Phys. Rev. Lett.</i> 58:908-10, 1987.
2,048	246	71	51	*Yalow R S & Berson S A. Immunoassay of plasma insulin in man. <i>J. Clin. Invest.</i> 39:1157-75, 1960. (14/77)
1,882	287	470	886	Yanisch-Perron C, Vieira J & Messing J. Improved M13 phage cloning vectors and host strains: nucleotide sequences of the M13mp18 and pUC19 vectors. <i>Gene</i> 33:103-19, 1985.

for quality control is therefore cautious and conservative. In an upcoming essay, we'll describe ISI's quality control expert system in greater detail. We will also review studies of citation error rates in various specialty journals.

### The Oldest Papers: A Possible Case of Delayed Recognition?

Table 2 shows the distribution of the 100 papers in this essay by decade of publication and indicates total citations, average citations per year, and 1988 citations. Cumulative data on the top 300 papers presented to date are shown in parentheses.

The two oldest papers in this essay were published in the 1930s. One is a 1937 *Journal of Biological Chemistry* article by William S. Hoffman, Chicago Medical School, Illinois, describing a rapid photoelectric method for measuring glucose in blood and urine. The other is by M.L. Anson, the Laboratories of The Rockefeller Institute for Medical Research, then at Princeton, New Jersey. Published in 1938 in the *Journal of General Physiology*, the paper describes hemoglobin assays for pepsin and other molecules.

The year-by-year citation profiles of both papers are illustrated in Figure 1. Citations to Hoffman's paper seem to fit the pattern for cases of delayed recognition. We don't know how often it was cited from 1937 to 1944, but it received no more than five citations per year from 1945 to 1959. Citations then increased rapidly to a peak of 180 in

1970, more than 30 years after the paper was published. It received a total of 2,210 citations from 1945 to 1988.

### Most Recent Papers on the List

Eleven articles were published in the 1980s. They are easily identified by scanning column C in Table 1: all have been cited at least 200 times per year.

Eight of these 1980s papers have been identified in previous studies of "hot" articles that were highly cited within the first two years of publication. They are by Michael J. Berridge, University of Cambridge, UK (1984);<sup>6,7</sup> Monique Castagna, Kobe University School of Medicine, Japan, *et al.* (1982);<sup>8,9</sup> Jack Kyte and Russell F. Doolittle, University of California, Davis (1982);<sup>9,10</sup> D.A. Melton, Harvard University, Cambridge, Massachusetts, *et al.* (1984);<sup>7,11</sup> Messing and Vieira (1982);<sup>9,12</sup> Vieira and Messing (1982);<sup>9,13</sup> Maw-Kuen Wu, University of Alabama, Huntsville, *et al.* (1987);<sup>14,15</sup> and Celeste Yanisch-Perron and colleagues, University of Minnesota (1985).<sup>16,17</sup>

The three exceptions are Andrew P. Feinberg and Bert Vogelstein, Johns Hopkins University School of Medicine, Baltimore, Maryland (1983); O.P. Hamill, Max Planck Institute for Biophysical Chemistry/Karl Friedrich Bonhoeffer Institute, Göttingen-Nikolausberg, Federal Republic of Germany, *et al.* (1981); and Peter J. Munson and David Rodbard, National Institutes of Health, Bethesda, Maryland (1980).

Table 2: Chronological distribution of the third 100 most-cited papers, SCT® 1945-1988. Data in parentheses are cumulated through the top 300 most-cited papers identified to date.

Decade	Number of Papers	Total Cites	Average Citations per year	Average 1988 Cites
1920s	0 (3)	0 (22,259)	0 (169)	0 (133)
1930s	2 (9)	4,468 (38,325)	51 (97)	31 (76)
1940s	12 (29)	24,786 (105,392)	48 (87)	44 (107)
1950s	19 (66)	38,489 (436,455)	61 (195)	52 (294)
1960s	36 (109)	72,279 (403,962)	77 (168)	84 (139)
1970s	20 (65)	40,758 (313,203)	136 (321)	171 (568)
1980s	11 (19)	22,620 (52,488)	348 (460)	690 (782)
TOTAL	100 (300)	203,390 (1,372,084)	103 (214)	153 (300)

### Why Treat Multipart Papers as Separate Publications?

In response to our first essay in this series,<sup>1</sup> we received a letter from Robert G. Parr, University of North Carolina, Chapel Hill.<sup>18</sup> He expressed surprise that a two-part paper he coauthored with Rudolph Pariser, E.I. du Pont de Nemours & Company, Inc., Wilmington, Delaware, in 1953 was not listed.<sup>19,20</sup> Pariser had written a *Citation Classic* commentary in 1978,<sup>21</sup> and the authors were aware that the papers had been cited over 3,000 times.

Both papers, which describe "A semi-empirical theory of the electronic spectra and electronic structure of complex unsaturated molecules," are included in Table 1. Part 1 received 1,955 citations through 1988, and the second part was cited 1,979 times. If they were treated as a single paper, the combined citation count would be 3,934. However, many of these are probably co-citations: that is, authors cite both parts in their bibliographies. For example, in 1988 parts 1 and 2 each received 29 citations, and 23 were co-citations.

These and other multipart papers are not treated as a single publication in ISI's citation studies for practical reasons. Frequently, parts in a series are published in different issues and volumes of a journal, and they can extend over several years. Also, the number and sequence of authors' names often vary. This makes it impractical for us to identify these separate articles as parts of

a series, or to create a single combined citation count for them in our rankings, either manually or by computer. The cost of editing would be prohibitively expensive.

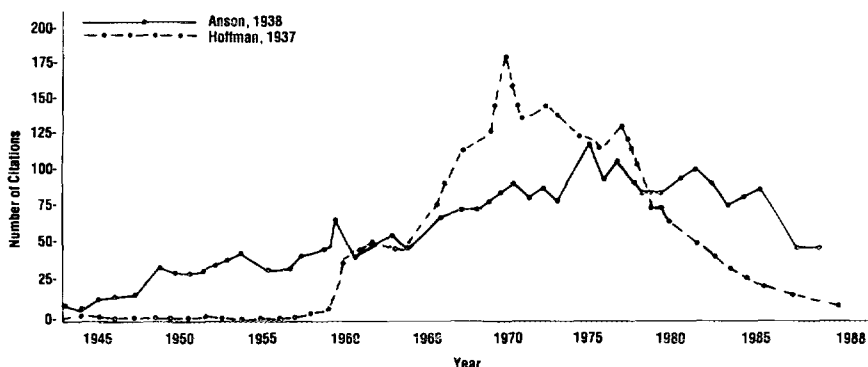
### Foreign Language Citation Classics

Two papers in Table 1 were published in French, and they are the only non-English articles listed. The 1953 paper by Pierre Grabar and Curtis A. Williams, Pasteur Institute, Paris, France, described a method for studying the electrophoretic and immunochemical properties of protein mixtures. Published in *Biochimica et Biophysica Acta*, the paper received 1,941 citations through 1988. It averaged 54 citations annually, reached a peak of 96 citations in 1965, and was cited 29 times in 1988.

The second French-language paper was published in 1967 in the *Journal de Microscopie* by Jean-Paul Thiéry, National Scientific Research Center, Paris. It discussed the "Demonstration of polysaccharides on thin sections by electron microscopy." Cited 1,853 times through 1988, the paper averaged 84 citations per year. It received 73 citations in 1988, compared to its peak of 135 citations in 1977.

Including the Grabar/Williams and Thiéry papers, three French-language articles have appeared in the 300 most-cited articles identified to date. In addition, three German articles have been included—two in Part 1,<sup>1</sup> and one in Part 2.<sup>2</sup> For a broader perspec-

Figure 1: Annual distribution of citations by year, *SCI*<sup>®</sup> 1945-1988, to the two papers published in the 1930s in this study. Full references are included in Table 1.



tive on language use in science, readers may refer to the recent *CC* essay on this subject.<sup>22</sup> The essay reprinted a citation analysis based on 1984-1988 *SCI* data from the *Annals of the American Academy of Political and Social Science*.

#### Nobel Laureates

Thirteen Nobel laureates are listed on 11 papers in Table 1. The prizewinners in medicine or physiology (and year of their awards) are Alan L. Hodgkin (1963), University of Cambridge; Bernard Katz (1970), University College, London, UK; George E. Palade (1974), The Rockefeller University, New York; Earl W. Sutherland (1971), Vanderbilt University, Nashville, Tennessee; John R. Vane (1982), Wellcome Research Labs, Beckenham, UK; and Rosalyn S. Yalow (1977), Veterans Administration Hospital, Bronx, New York.

The Nobel chemists listed are R. Bruce Merrifield (1984), Stanford Moore (1972), and William H. Stein (1972), all of The Rockefeller University; and Frederick Sanger (1958), Medical Research Council, Cambridge, UK. The physics prizewinners are Philip W. Anderson (1977), Bell Labs, Murray Hill, New Jersey; and Sheldon L. Glashow (1979) and John H. Van Vleck (1977), both of Harvard University.

Through the *SCI* Top 300, 54 papers have been authored by 38 Nobel Prize winners. Table 3 shows eight Nobel laureates who have authored two or more papers listed among the 300 all-time *Citation Classics* identified to date. Moore is the leader with seven papers, six of which were coauthored with Stein.

#### Prolific Authors

Messing and Vieira are listed on three papers in Table 1, and five authors each have two papers: Oliver H. Lowry, Public Health Research Institute of the City of New York; Tom Maniatis, Harvard University; Pariser and Parr; and Michael Somogyi, Jewish Hospital, St. Louis, Missouri. Lowry is well known to *CC* readers as the citation laureate extraordinaire, whose 1951 *Citation Classic* paper on protein determination has achieved phenomenal impact—about 200,000 citations to date.<sup>23</sup> A paper reporting an improvement to that method is included in Table 1. By Gary L. Peterson, University of Wisconsin, Madison, the 1977 *Analytical Biochemistry* paper has been cited 2,214 times through 1988.

Eleven authors account for at least three papers in the top 300 all-time *Citation Classics* identified to date. As noted above, Moore and Stein have seven and six papers, respectively. Bruce N. Ames, University of



**Table 3: Nobel Prize winners with more than one paper appearing among the 300 most-cited papers, *SCI*<sup>®</sup> 1945-1988. A=name. B=year and prize. C=number of papers.**

A	B	C
Walter Gilbert	1980/Chemistry	2
Alan L. Hodgkin	1963/Physiology or Medicine	2
Jacques Monod	1965/Physiology or Medicine	2
Stanford Moore	1972/Chemistry	7
George E. Palade	1974/Physiology or Medicine	2
Frederick Sanger	1958/Chemistry	2
William H. Stein	1972/Chemistry	6
John R. Vane	1982/Physiology or Medicine	2

California, Berkeley; Don T. Cromer, University of California, Los Alamos Scientific Laboratory, New Mexico; and Messing follow with four each. The following authors each account for three papers: William M. Hunter, Imperial Cancer Research Fund, London; Morris J. Karnovsky, Harvard Medical School, Boston, Massachusetts; Ulrich K. Laemmli, University of Geneva, Switzerland; Lowry; Somogyi; and Vieira.

#### Journals of the *SCI* Top 300

Table 4 presents 59 journals that published the third group of 100 most-cited papers in this essay. Once again, the *Journal of Biological Chemistry* is the leader with 12 papers, bringing its total through the *SCI* Top 300 to 43. It is followed by the *Biochemical Journal*, which has 6 articles in this study and 18 overall.

Journals that have published at least five articles ranked among the *SCI* Top 300 are shown in Table 5. These 15 journals account for 166 articles, or 55 percent of the total presented to date. When this series eventually covers the top 1,000-1,500 papers, the ranking will probably turn out to be a fairly good list of the most significant journals of science. We'll compare this with other citation indicators of significance in upcoming *CC* essays on the top science and social-sciences journals. The range of indicators includes total articles (productivity), citation frequency (impact), impact factor (average

**Table 4: The journals that published the third group of most-cited papers, *SCI*<sup>®</sup> 1945-1988. A=title, with first year of publication in parentheses. B=number of most-cited articles.**

A	B
J. Biol. Chem. (1905)	12
Biochem. J. (1906)	6
J. Mol. Biol. (1959)	5
Anal. Biochem. (1960)	3
Gene (1977)	3
J. Chem. Phys. (1931)	3
J. Immunol. (1916)	3
Nature (1869)	3
Phys. Rev. (1893)	3
Biochim. Biophys. Acta (1947)	2
Cell (1974)	2
J. Amer. Chem. Soc. (1879)	2
J. Cell Biol. (1962)	2
J. Clin. Invest. (1924)	2
J. Exp. Med. (1896)	2
J. Histochem. Cytochem. (1953)	2
Meth. Enzymology (1955)	2
Science (1880)	2
Acta Crystallogr. A—Cryst. Phys. (1968)	1
Acta Pathol. Microbiol. Scand. (1924)	1
Acta Physiol. Scand. (1940)	1
Acta Radiologica (1921)	1
Advan. Prot. Chem. (1944)	1
Amer. J. Clin. Pathol. (1931)	1
Amer. J. Trop. Med. Hyg. (1952)	1
Anal. Chem. (1929)	1
Anal. Chim. Acta (1947)	1
Arch. Biochem. Biophys. (1951)	1
Biochemistry—USA (1956)	1
Biochem. Biophys. Res. Commun. (1959)	1
Biochem. Pharmacol. (1958)	1
Brit. J. Haematol. (1955)	1
Bull. Rheumat. Dis. (1950)	1
Comput. J. (1958)	1
Eur. J. Biochem. (1967)	1
Exp. Cell Res. (1950)	1
Immunology (1958)	1
J. Anat. (1916)	1
J. Appl. Phys. (1948)	1
J. Chronic Dis. (1955)	1
J. Gen. Physiol. (1918)	1
J. Lab. Clin. Med. (1915)	1
J. Lipid Res. (1959)	1
J. Microsc.—Paris (1962)	1
J. Neurol. Neurosurg. Psychiat. (1944)	1
J. Pharmacol. Exp. Ther. (1909)	1
J. Phys. Chem. (1896)	1
J. Physiology (1878)	1
Math. Comput. (1943)	1
Nucl. Acid. Res. (1974)	1
Pflügers Arch.—Eur. J. Physiol. (1968)	1
Pharmacol. Rev. (1949)	1
Phys. Rev. D—Part. Fields (1970)	1
Phys. Rev. Lett. (1958)	1
Physiol. Rev. (1921)	1
Proc. Nat. Acad. Sci. USA (1915)	1
Proc. Roy. Soc. London Ser. A (1905)	1
Proc. Soc. Exp. Biol. Med. (1903)	1
Stain Technol. (1926)	1

**Table 5: Journals that published five or more of the top 300 most-cited papers, SCI® 1945-1988.**

A=title, with first year of publication in parentheses.

B=number of most-cited papers appearing in the journal.

A	B
J. Biol. Chem. (1905)	43
Biochem. J. (1906)	18
Nature (1869)	13
J. Mol. Biol. (1959)	12
J. Chem. Phys. (1931)	11
Proc. Nat. Acad. Sci. USA (1915)	11
Anal. Biochem. (1960)	10
J. Cell Biol. (1962)	7
J. Histochem. Cytochem. (1953)	7
J. Exp. Med. (1869)	6
Meth. Enzymology (1955)	6
Phys. Rev. (1893)	6
Science (1880)	6
Anal. Chem. (1929)	5
J. Amer. Chem. Soc. (1879)	5

citations per article), and number of articles cited at least 50, 100, or 1,000 times.

### Computer Mathematics Is Factored into the Classics Equation

Three statistics and applied mathematics journals were included in our first essay,<sup>1</sup> with one paper each among the SCI Top 100: the journals of the American Statistical Association, Royal Statistical Society (Series B: Methodological), and the Society for Industrial and Applied Mathematics. The papers have been described by the authors in *Citation Classic* commentaries.<sup>24-26</sup>

No math journals were in the second group of 100 most-cited articles, but two computer mathematics journals appear in this study: *Computer Journal* and *Mathematics of Computation*. Both are new to the list, so their articles in Table 1 are their most cited through 1988.

R. Fletcher, University of Leeds, UK, and M.J.D. Powell, Atomic Energy Research Establishment, Harwell, UK, described "A

rapidly convergent descent method for minimization." The 1963 *Computer Journal* paper received 1,948 citations and averaged 75 per year. It reached a citation peak of 126 as late as 1984 and was cited 112 times in 1988. The other is a 1965 paper by James W. Cooley, IBM Watson Research Center, Yorktown Heights, New York, and John W. Tukey, Bell Labs. It presented a computer algorithm for calculating complex Fourier series and was cited 1,845 times through 1988. The paper received 78 citations in 1988, down from a peak of 112 in 1977.

Unfortunately, we don't yet have the benefit of a *Citation Classic* commentary on either paper. As stated earlier, 35 of the 100 papers in this study, and 136 of the top 300, have already been described in *Citation Classic* commentaries. Thus, there are still 164 papers that have not yet been discussed by the authors or others familiar with the work but should be included in the *Citation Classic* series. We continue to invite all authors of these "orphaned" classics to contribute their personal insights and recollections.

### The Next 100 Supercited Papers

In the next essay in this series, we will identify the all-time *Citation Classics* ranked number 301-400 on the list of papers most cited from 1945 to 1988. Specific papers of interest will be highlighted, and their citation patterns will be discussed. Also, data on chronological distributions, Nobel laureates, prolific authors, and journals will be presented and cumulated through the SCI Top 400.

\* \* \* \* \*

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