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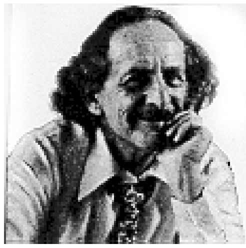

Current Comments®

The Articles Most Cited in 1961-1982. 4. 100 Additional *Citation Classics*

Number 40 October 1, 1984

This essay is a continuation of our multipart series on the papers most cited from 1961 to 1982. Using *Science Citation Index*® (*SCI*®), we've previously identified 300 papers[1-3] cited at least 1,188 times in this 22-year period.

All of the papers we've identified to date can be considered classics in the scientific literature. That they are so frequently referenced indicates their usefulness and relevance to the research of many scientists, for whatever reasons. Certain methodology papers are highly cited because they describe elegant procedures or reliable strategies for attacking research problems. Theoretical works often achieve high impact if they inspire new experiments or when others test the hypotheses they propose. Such papers often symbolize paradigm shifts within a discipline. Timely reviews may also be frequently cited because they provide overviews of various lines of research. Reviews can summarize the consensus of scientific opinion on a given topic and simplify the task of documenting earlier research.

In any event, the papers identified in these studies do not necessarily represent the "best" or most "important" research. That point bears constant repetition to prevent the mistaken impression that these studies encourage overly simplistic criteria for admission to the science "hall of fame." Unlike sports fans, who thrive on statistics about the best athletes, scientists are often reluctant to accept any quantitative indicators. But scientific research is now such a large and widespread enterprise that it is easy to lose sight of some of the highest-impact achievers.

Table 1 presents full bibliographic information on the 100 classics in this study. They are arranged in alphabetic order by first author. The number of 1961-1982 citations is shown, followed by 1983 citations in parentheses. Each of these papers was cited at least 1,032 times. More than 20 million papers were cited at least once during this 22-year period. Of these, only 433 are "kiloclassics"—i.e., papers that have been cited more than 1,000 times. When books are included in these citation analyses, we'll probably find that no more than 1,000 publications are kiloclassics.

Asterisks indicate the 33 papers that have already been featured as *Citation Classics*™ in *Current Contents*® (*CC*®). The issue, year, and edition of *CC* in which the author's commentary appeared are shown after the reference. The authors listed in Table 1 are invited to submit commentaries on their classic papers if they have not done so already.

A number symbol (#) in Table 1 identifies papers that were also included in a 1974 study of the most-cited articles in the 1961-1972 *SCI*.[4] Of the 100 classics identified 10 years ago, 83 are among the 400 most-cited papers presented in this series to date.

Life-sciences papers dominate the list in this and previous studies. We've explained the reason for this before.[2] However, the proportion of life-sciences papers is declining as the series is extended. For example, 85 life-sciences papers were identified in the first group, 77 in the second, and 80 in the third. There are 72 life-sciences papers in this study. The number of physics and chemistry papers is increasing. Physics accounts for 15 papers in Table 1, compared with 6 in the first group of classics we identified, 11 in the second, and 7 in the third. Chemistry accounted for 9 papers in part one, 10 in part two, 10 in part three, and 13 in this study.

I regret that we have never received a commentary from Joel H. Hildebrand, who coauthored with H.A. Benesi the paper on the interaction of iodine with aromatic hydrocarbons. Hildebrand taught chemistry to me and over 100,000 other students.[5] He recently died at the age of 101.[6]

Table 2 shows the publication-year distribution for the 100 classics identified here. It is similar to the distribution reported for the 300 most-cited articles. The oldest paper was published in 1930 in *Physical Review*. J.C. Slater, Harvard University, Cambridge, Massachusetts, described a simple method for approximating wave functions and energy levels of atoms and ions. The paper was cited about 1,200 times from 1961 to 1982. It received 35 citations in 1983, indicating that physicists not only still rely on Slater's atomic shielding constants but also feel compelled to explicitly cite the primordial reference more than 50 years later.

The most recent paper was published in 1977 in *Gene*. F. Bolivar, University of California, San Francisco, and colleagues discussed a method for the construction and characterization of new cloning vehicles. The paper has been referred to in more than 1,500 publications during the past seven years. This unusual rate of citation reflects the rapid growth of genetic engineering and recombinant DNA technology in recent years. It is significant that this paper was cited almost 350 times in 1983, more than any other paper listed.

Perhaps more than in other fields, molecular biology depends on methodological innovations to advance the frontiers of research. P.A. Sharp, Massachusetts Institute of Technology, Cambridge, suggested this point in a commentary on his assay for restriction endonucleases. "Advances in molecular biology are frequently the product of the development of new methodology. Perhaps the most striking recent example of this is the impact that recombinant DNA technology has had. Publications that make novel contributions to the development of new methodology are widely read and frequently referenced. [We] described this type of methodology at a time when the molecular biological community was discovering the multiple uses of restriction endonucleases."[7] Sharp's classic method, coauthored with B. Sugden and J. Sambrook, Cold Spring Harbor Laboratory, New York, was cited more than 1,200 times from 1973 to 1983.

A methodological paper sometimes becomes highly cited after refinements in related technologies make its application more practical. T.F. Anderson, Fox Chase Cancer Center, Philadelphia, noted that his paper on techniques for preserving the three-dimensional structure of specimens prepared for electron microscopes was cited more frequently after these instruments were perfected. "Electron microscopists were very slow to adopt the method, even though everyone knew about it from the beautiful steroscopic pictures...I showed at meetings in both the US and Europe.... It wasn't until late-1960, when scanning electron microscopes became practical and useful, that the method became popular."[8] Anderson's 1951 paper received just 25 citations from 1955 to 1960. It was cited about 1,100 times from 1961 to 1982, and 51 times in 1983.

Although methodology papers commonly appear in citation-based studies, many theoretical works are also included. For example, Leonard Hayflick, then at Wistar Institute of Anatomy and Biology, Philadelphia, expanded on a theory of cellular aging in his 1965 paper published in *Experimental Cell Research* entitled "The limited *in vitro* lifetime of human diploid cell strains." In fact, this

Table 1: The fourth 100 most-cited articles, *SCI*® 1961-1982, arranged in alphabetic order by first author. A = 1961-1982 citations. 1983 citations appear in parentheses. B = bibliographic data. An asterisk (*) indicates that the paper was the subject of a *Citation Classic*™ commentary. The issue, year, and edition of *CC*® in which these commentaries appeared are listed in parentheses. A number symbol (#) indicates that the paper appeared in the 1974 list of most-cited articles.

A	B
1112 (92)	**Ames B N, Durston W E, Yamasaki E & Lee F D.** Carcinogens are mutagens: a simple test system combining liver homogenates for activation and bacteria for detection. *Proc. Nat. Acad. Sci. US* 70:2281-5, 1973.
1086 (51)	***Anderson T F.** Techniques for the preservation of three-dimensional structure in preparing specimens for the electron microscope. *Trans. NY Acad. Sci.* 13:130-4, 1951. (49/82/LS)
1060 (146)	**Arunlakshana O & Schild H O.** Some quantitative uses of drug antagonists. *Brit. J. Pharmacol.* 14:48-58, 1959.
1119 (54)	**Benesi H A & Hildebrand J H.** A spectrophotometric investigation of the interaction of iodine with aromatic hydrocarbons. *J. Amer. Chem. Soc.* 71:2703-7, 1949.
1094 (17)	***Bertler A, Carlsson A & Rosengren E.** A method for the fluorimetric determination of adrenaline and noradrenaline in tissues. *Acta Physiol. Scand.* 44:273-92, 1958. (49/79/LS)
1184 (161)	**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. *J. Cell Biol.* 67:835-51, 1975.
1169 (345)	**Bolivar F, Rodriguez R L, Greene P J, Betlach M C, Heyneker H L, Boyer H W, Crosa I H & Fakow S.** Construction and characterization of new cloning vehicles. II. A multipurpose cloning system. *Gene* 2:95-113, 1977.
1048 (123)	**Bondi A.** Van der Waals' volumes and radii. *J. Phys. Chem.* 68:441-51, 1964.
1137 (46)	**Bonsnes R W & Taussky H H.** On the colorimetric determination of creatinine by the Jaffe reaction. *J. Biol. Chem.* 158:581-91, 1945.
1150 (43)	***Bradley T R & Metcalf D.** The growth of mouse bone marrow cells *in vitro*. *Aust. J. Exp. Biol. Med. Sci.* 44:287-99, 1966. (40/79/LS)
1075 (103)	**Brazeau P, Vale W, Burgus R, Ling N, Butcher M, Rivier J & Guillemin R.** Hypothalamic polypeptide that inhibits the secretion of immunoreactive pituitary growth hormone. *Science* 179:77-9, 1973.
1043 (4)	**#*Bush I E.** Methods of paper chromatography of steroids applicable to the study of steroids in mammalian blood tissues. *Biochem. J.* 50:370-8, 1952. (3/84/LS)
1035 (38)	***Carr H Y & Purcell E M.** Effects of diffusion on free precession in nuclear magnetic resonance experiments. *Phys. Rev.* 94:630-8, 1954. (20/83/PC&ES)
1054 (19)	**Ceriotti G.** Determination of nucleic acids in animal tissues. *J. Biol. Chem.* 214:59-70, 1955.
1043 (48)	**Cerottini J-C & Brunner K T.** Cell-mediated cytotoxicity, allograft rejection, and tumor immunity. *Advan. Immunol.* 18:67-132, 1974.
1174 (97)	***Chen R F.** Removal of fatty acids from serum albumin by charcoal treatment. *J. Biol. Chem.* 242:173-81, 1967. (13/82/LS)
1033 (75)	**Cleland W W.** The statistical analysis of enzyme kinetic data. *Advan. Enzymol. Relat. Areas Mol.* 29:1-32, 1967.
1100 (51)	**Clementi E & Raimondi D L.** Atomic screening constants from SCF functions. *J. Chem. Phys.* 38:2686-9, 1963.
1162 (126)	***Cutler S J & Ederer F.** Maximum utilization of the life table method in analyzing survival. *J. Chronic Dis.* 8:699-712, 1958. (16/79/CP)
1070 (127)	**Ditchfield R, Hehre W J & Pople J A.** Self-consistent molecular-orbital methods. IX. An extended Gaussian-type basis for molecular-orbital studies of organic molecules. *J. Chem. Phys.* 54:724-8, 1971.
1032 (152)	**Dunning T H.** Gaussian basis functions for use in molecular calculations. I. Contraction of (9*s*5*p*) atomic basis sets for the first-row atoms. *J. Chem. Phys.* 53:2823-33, 1970.
1040 (27)	**Farr R S.** A quantitative immunochemical measure of the primary interaction between I*BSA and antibody. *J. Infec. Dis.* 103:239-62, 1958.
1157 (34)	**Fessenden R W & Schuler R H.** Electron spin resonance studies of transient alkyl radicals. *J. Chem. Phys.* 39:2147-95, 1963.
1144 (26)	***Fredrickson D S, Levy R I & Lees R S.** Fat transport in lipoproteins—an integrated approach to mechanisms and disorders. Glyceride transport. *N. Engl. J. Med.* 276:94-103, 1967. (3/78)
1154 (26)	***Fredrickson D S, Levy R I & Lees R S.** Fat transport in lipoproteins—an integrated approach to mechanisms and disorders. Type II hyperlipoproteinemia. *N. Engl. J. Med.* 276:215-25, 1967. (3/78)

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1182 (96)	**Giles K W & Myers A.** An improved diphenylamine method for the estimation of deoxyribonucleic acid. *Nature* 206:93, 1965.
1146 (52)	**Glauber R J.** Coherent and incoherent states of the radiation field. *Phys. Rev.* 131:2766-88, 1963.
1068 (54)	**Goldman D E.** Potential, impedance, and rectification in membranes. *J. Gen. Physiol.* 27:37-60, 1943.
1167 (47)	**Hammond G S.** A correlation of reaction rates. *J. Amer. Chem. Soc.* 77:334-40, 1955.
1069 (76)	**Hartley B S.** Strategy and tactics in protein chemistry. *Biochem. J.* 119:805-22, 1970.
1145 (57)	**Hayflick L.** The limited *in vitro* lifetime of human diploid cell strains. *Exp. Cell Res.* 37:614-36, 1965.
1114 (69)	***Hedrick J L & Smith A J.** Size and charge isomer separation and estimation of molecular weights of proteins by disc gel electrophoresis. *Arch. Biochem. Biophys.* 126:155-64, 1968. (48/79/LS)
1042 (72)	***Henle G & Henle W.** Immunofluorescence in cells derived from Burkitt's lymphoma. *J. Bacteriol.* 91:1248-56, 1966. (12/84/LS)
1104 (37)	***Huxley H E.** Electron microscope studies on the structure of natural and synthetic protein filaments from striated muscle. *J. Mol. Biol.* 7:281-308, 1963. (29/79/LS)
1051 (20)	**Jacob F, Brenner S & Cuzin F.** On the regulation of DNA replication in bacteria. *Cold Spring Harbor Symp.* 28:329-48, 1963.
1046 (10)	***Jacob M & Wick G C.** On the general theory of collisions for particles with spin. *Ann. Phys. NY* 7:404-28, 1959. (21/79/PC&ES)
1095 (40)	**Karnovsky M J.** The ultrastructural basis of capillary permeability studied with peroxidase as a tracer. *J. Cell Biol.* 35:213-36, 1967.
1117 (95)	**Karnovsky M J & Roots L.** A "direct-coloring" thiocholine method for cholinesterases. *J. Histochem. Cytochem.* 12:219-21, 1964.
1048 (25)	***Kellenberger E, Ryter A & Sechaud J.** Electron microscope study of DNA-containing plasms. II. Vegetative and mature phage DNA as compared with normal bacterial nucleoids in different physiological states. *J. Biophys. Biochem. Cytol.* 4:671-8, 1958. (7/80/LS)
1081 (13)	**Kisslinger L S & Sorensen R A.** Spherical nuclei with simple residual forces. *Rev. Mod. Phys.* 35:853-915, 1963.
1050 (65)	***Kramer C Y.** Extension of multiple range tests to group means with unequal numbers of replications. *Biometrics* 12:307-10, 1956. (44/77)
1047 (109)	***Lands A M, Arnold A, McAuliff J P, Luduena F P & Brown T G.** Differentiation of receptor systems activated by sympathomimetic amines. *Nature* 214:597-8, 1967. (47/81/LS)
1141 (81)	**Laurell C-B.** Antigen-antibody crossed electrophoresis. *Anal. Biochem.* 10:358-61, 1965.
1041 (51)	**Laurent T C & Killander J.** A theory of gel filtration and its experimental verification. *J. Chromatogr.* 14:317-30, 1964.
1160 (164)	**Littlefield J W.** Selection of hybrids from matings of fibroblasts *in vitro* and their presumed recombinants. *Science* 145:709-10, 1964.
1068 (16)	***Lowry O H & Lopez J A.** The determination of inorganic phosphate in the presence of labile phosphate esters. *J. Biol. Chem.* 162:421-8, 1946. (31/81/LS)
1119 (98)	**Maizel J V.** Polyacrylamide gel electrophoresis of viral proteins. *Meth. Virology* 5:179-246, 1971.
1075 (233)	**Maniatis T, Jeffrey A & Kleid D G.** Nucleotide sequence of the rightward operator of phage λ. *Proc. Nat. Acad. Sci. US* 72:1184-8, 1975.
1170 (194)	***Mantel N & Haenszel W.** Statistical aspects of the analysis of data from retrospective studies of disease. *J. Nat. Cancer Inst.* 22:719-48, 1959. (26/81/LS)
1050 (75)	**Maroko P R, Kjekshus J K, Sobel B E, Watanabe T, Covell J W, Ross J & Braunwald E.** Factors influencing infarct size following experimental coronary artery occlusions. *Circulation* 43:67-82, 1971.
1124 (70)	**McMillan W L.** Transition temperature of strong-coupled superconductors. *Phys. Rev.* 167:331-44, 1968.
1037 (64)	***Miles A A, Misra S S & Irwin J O.** The estimation of the bactericidal power of the blood. *J. Hyg.* 38:732-49, 1938. (37/79/LS)
1149 (85)	***Miller G L.** Protein determination for large numbers of samples. *Anal. Chem.* 31:964, 1959. (9/80/LS)
1107 (53)	***Mittal K K, Mickey M R, Singal D P & Terasaki P I.** Serotyping for homotransplantation. XVIII. Refinement of microdroplet lymphocyte cytotoxicity test. *Transplantation* 6:913-27, 1968. (26/79/LS)
1132 (15)	***Moor H & Muhlethaler K.** Fine structure in frozen-etched yeast cells. *J. Cell Biol.* 17:609-28, 1963. (19/81/LS)

A	B
1155 (70)	**Mori H.** Transport, collective motion, and Brownian motion. *Prog. Theor. Phys. Kyoto* 33:423-55, 1965.
1065 (36)	**Mulliken R S.** Molecular compounds and their spectra. II. *J. Amer. Chem. Soc.* 74:811-24, 1952.
1085 (121)	**Murphy J & Riley J P.** A modified single solution method for the determination of phosphate in natural waters. *Anal. Chim. Acta* 27:31-6, 1962.
1077 (95)	**Neville D M.** Molecular weight determination of protein-dodecyl sulfate complexes by gel-electrophoresis in a discontinuous buffer system. *J. Biol. Chem.* 246:6328-34, 1971.
1078 (10)	**Nirenberg M W & Leder P.** RNA codewords and protein synthesis. *Science* 145:1399-407, 1964.
1153 (11)	**#Nirenberg M W & Matthaei J H.** The dependence of cell-free protein synthesis in *E. coli* upon naturally occurring or synthetic polyribonucleotides. *Proc. Nat. Acad. Sci. US* 47:1588-602, 1961.
1158 (73)	**Northcliffe L C & Schilling R F.** Range and stopping-power tables for heavy ions. *Nucl. Data Sect. A* 7:233-463, 1970.
1090 (101)	**Omura T & Sato R.** The carbon monoxide-binding pigment of liver microsomes. II. Solubilization, purification, and properties. *J. Biol. Chem.* 239:2379-85, 1964.
1086 (48)	**Onsager L.** Electric moments of molecules in liquids. *J. Amer. Chem. Soc.* 58:1486-93, 1936.
1127 (39)	**Oyama V I & Eagle H.** Measurement of cell growth in tissue culture with a phenol reagent (Folin-Ciocalteau). *Proc. Soc. Exp. Biol. Med.* 91:305-7, 1956.
1048 (35)	**Park J T & Johnson M J.** A submicrodetermination of glucose. *J. Biol. Chem.* 181:149-51, 1949.
1112 (15)	**Partridge S M.** Filter-paper partition chromatography of sugars. 1. General description and application to the qualitative analysis of sugars in apple juice, egg white, and foetal blood of sheep. *Biochem. J.* 42:238-50, 1948.
1178 (10)	***Partridge S M.** Aniline hydrogen phthalate as a spraying reagent for chromatography of sugars. *Nature* 164:443, 1949. (14/79/AB&ES)
1044 (50)	**Peacock A C & Dingman C W.** Molecular weight estimation and separation of ribonucleic acid by electrophoresis in agarose-acrylamide composite gels. *Biochemistry* 7:668-74, 1968.
1083 (44)	***Pearson R G.** Hard and soft acids and bases. *J. Amer. Chem. Soc.* 85:3533-9, 1963. (23/80/PC&ES)
1075 (23)	**Penman S.** RNA metabolism in the HeLa cell nucleus. *J. Mol. Biol.* 17:117-30, 1966.
1039 (21)	***Perey F G.** Optical-model analysis of proton elastic scattering in the range of 9 to 22 MeV. *Phys. Rev.* 131:745-63, 1963. (27/80/PC&ES)
1054 (11)	**#Peterson E A & Sober H A.** Chromatography of proteins. I. Cellulose ion-exchange adsorbents. *J. Amer. Chem. Soc.* 78:751-5, 1956.
1059 (31)	**Pople J A, Beveridge D L & Dobosh P A.** Approximate self-consistent molecular-orbital theory. V. Intermediate neglect of differential overlap. *J. Chem. Phys.* 47:2026-33, 1967.
1054 (7)	***Post R L, Merritt C R, Kinsolving C R & Albright C D.** Membrane adenosine triphosphatase as a participant in the active transport of sodium and potassium in the human erythrocyte. *J. Biol. Chem.* 235:1796-802, 1960. (13/81/LS)
1124 (35)	***Quastler H & Sherman F G.** Cell population kinetics in the intestinal epithelium of the mouse. *Exp. Cell. Res.* 17:420-38, 1959. (48/80/LS)
1035 (69)	***Radloff R, Bauer W & Vinograd J.** A dye-buoyant-density method for the detection and isolation of closed circular duplex DNA: the closed circular DNA in HeLa cells. *Proc. Nat. Acad. Sci. US* 57:1514-21, 1967. (23/81/LS)
1103 (69)	**Reid R V.** Local phenomenological nucleon-nucleon potentials. *Ann. Phys. NY* 50:411-48, 1968.
1101 (42)	***Reissig J L, Strominger J L & Leloir L F.** A modified colorimetric method for the estimation of *N*-acetylamino sugars. *J. Biol. Chem.* 217:959-66, 1955. (28/79/LS)
1065 (18)	***Robison G A, Butcher R W & Sutherland E W.** Cyclic AMP. *Annu. Rev. Biochem.* 37:149-74, 1968. (18/79/LS)
1127 (17)	**Sanger F.** The free amino groups of insulin. *Biochem. J.* 39:507-15, 1945.
1076 (34)	**Sarnoff S J, Braunwald E, Welch G H, Case R B, Stainsby W N & Macruz R.** Hemodynamic determinants of oxygen consumption of the heart with special reference to the tension-time index. *Amer. J. Physiol.* 192:148-56, 1958.
1150 (36)	**Schwert G W & Takenaka Y.** A spectrophotometric determination of trypsin and chymotrypsin. *Biochim. Biophys. Acta* 16:570-5, 1955.
1067 (17)	**Seifter S, Dayton S, Novic B & Muntwyler E.** The estimation of glycogen with the anthrone reagent. *Arch. Biochem.* 25:191-200, 1950.

A	B
1151 (68)	*Sharp P A, Sugden B & Sambrook J. Detection of two restriction endonuclease activities in *Haemophilus parainfluenzae* using analytical agarose-ethidium bromide electrophoresis. *Biochemistry* 12:3055-63, 1973. (3/82/LS)
1059 (58)	*Skipski V P, Peterson R F & Barclay M. Quantitative analysis of phospholipids by thin-layer chromatography. *Biochem. J.* 90:374-8, 1964. (1/78)
1147 (23)	**Skou J C.** The influence of some cations on an adenosine triphosphatase from peripheral nerves. *Biochim. Biophys. Acta* 23:394-401, 1957.
1075 (39)	**Slater J C.** A simplification of the Hartree-Fock method. *Phys. Rev.* 81:385-90, 1951.
1157 (35)	**Slater J C.** Atomic shielding constants. *Phys. Rev.* 36:57-64, 1930.
1162 (27)	**Somogyi M.** A new reagent for the determination of sugars. *J. Biol. Chem.* 160:61-8, 1945.
1056 (10)	**Sottocasa G L, Kuylenstierna B, Ernster L & Bergstrand A.** An electron-transport system associated with the outer membrane of liver mitochondria. *J. Cell Biol.* 32:415-38, 1967.
1047 (163)	**Spudich J A & Watt S.** 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. *J. Biol. Chem.* 246:4866-71, 1971.
1044 (8)	**Stavitsky A B.** Micromethods for the study of proteins and antibodies. I. Procedure and general applications of hemagglutination and hemagglutination-inhibition reactions with tannic acid and protein-treated red blood cells. *J. Immunol.* 72:360-7, 1954.
1085 (107)	**Steiner A L, Parker C W & Kipnis D M.** Radioimmunoassay for cyclic nucleotides. I. Preparation of antibodies and iodinated cyclic nucleotides. *J. Biol. Chem.* 247:1106-13, 1972.
1077 (63)	**Taussky H H & Shorr E.** A microcolorimetric method for the determination of inorganic phosphorus. *J. Biol. Chem.* 202:675-85, 1953.
1148 (51)	**Taylor R B, Duffus W P H, Raff M C & de Petris S.** Redistribution and pinocytosis of lymphocyte surface immunoglobulin molecules induced by anti-immunoglobulin antibody. *Nature New Biol.* 233:225-9, 1971.
1169 (115)	**Weber K, Pringle J R & Osborn M.** Measurement of molecular weights by electrophoresis on SDS-acrylamide gel. *Meth. Enzymology* 26:3-27, 1972.
1080 (41)	**Woodward R B & Hoffmann R.** The conservation of orbital symmetry. *Angew. Chem. Int. Ed.* 8:781-853, 1969.
1183 (220)	*Yam L T, Li C Y & Crosby W H. Cytochemical identification of monocytes and granulocytes. *Amer. J. Clin. Pathol.* 55:283-90, 1971. (50/80/CP)
1044 (45)	**Yemm E W & Cocking E C.** The determination of amino-acids with ninhydrin. *Analyst* 80:209-14, 1955.

Table 2: Chronological distribution of publication dates of the fourth 100 most-cited papers, 1961-1982 *SCI®*. A=publication date. B=number of papers.

A	B
1930s	3
1940s	9
1950s	27
1960s	42
1970s	19
	100

paper updates the research Hayflick and coauthor P.S. Moorhead first reported in 1961 in the same journal.[9] That 1961 paper was listed in the second part of this series.[2] Hayflick, now at the University of Florida, Gainesville, wrote a *Citation Classic* commentary on it,[10] which we quoted extensively earlier.[2]

Another important theoretical work is the 1969 paper by R.B. Woodward, Harvard University, and R. Hoffmann, Cornell University, New York. The paper described the theory of conservation of orbital symmetry, a basic principle of chemical reactions. It was cited more than 1,100 times from 1969 to 1983.

Both Woodward and Hoffmann received the Nobel prize for chemistry, in 1965 and 1981, respectively. In a previous essay,[11] we reported Hoffmann's assertion that Woodward would have won a second Nobel prize if he were alive today.[12] Eight other Nobel laureates appear in Table 1: R. Guillemin, F. Jacob, R.S. Mulliken, M.W. Nirenberg, L. Onsager, L.F. Leloir, E.W. Sutherland, and F. Sanger. In a forthcoming study, we will discuss in detail how often Nobelists have written classic papers.

Review articles may also become milestone papers in their field. Their impact often equals or exceeds that of classic methodological or theoretical works. For example, G.A. Robison, University of Texas, Houston, coauthored a review on cyclic AMP with R.W. Butcher and Sutherland. For this and other review articles, Robison received the first National Academy of Sciences Award for Excellence in Scientific Reviewing.

When we publish the next essay in this series, we will have identified the 500 most-cited articles in the 1961-1982 *SCI*. In addition to discussing the next group of 100 classics, we'll provide tables summarizing the distribution of all 500 papers by field, journal, year of publication, and so on. Similar summaries will be presented once we've listed the 1,000 most-cited articles.

Even if we continue this series to include the 10,000 most-cited papers, we would not necessarily have identified all of the primordial papers acknowledged to be classic research. A variety of normalizations are necessary to determine the appropriate citation or publication thresholds for each discipline and, indeed, the specific subtopics even within the life sciences. We have selected some small-field papers as *Citation Classics* by relying on analyses of particular journals. Perhaps a better strategy would be to apply our research front clustering techniques. We plan to identify research fronts over a decade or longer so that the core or classic papers for even the smallest specialties will surface.

We invite *CC* readers to recommend to us papers that for one reason or another fall into the category of uncited or rarely cited classics. As in the case of the synthesis of naloxone,[13] some important scientific discoveries are not reported in journals. They may instead be contained in patents, books, or informal communications, for example. If important discoveries are reported in relatively accessible journals, then it is important to understand why, when, and how they remain uncited. With the help of our readers, we can let these "hidden" or delayed-recognition classics stand up and be counted by peer recognition if not by citation analysis.

* * * * *

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