

Selecting the All-Time Citation Classics. Here Are the  
Fifty Most Cited Papers for 1961-1972.

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Number 2

About six years ago we compiled a list of the 50 papers most cited in the *Science Citation Index*® in 1967.<sup>1</sup> Recently, we prepared a similar list for the entire period 1961 to 1972. Though the world's literature has doubled during the interim, the list of super-cited papers has remained remarkably stable. Only ten 'new' papers have replaced papers on the earlier list. This would seem to provide an elementary definition of a classic. Consider, e.g., that W. C. Schneider's paper, #45 concerning pentose nucleic acid determination, was published in 1945.

I don't think there is any significance to the particular 'rank' achieved by the papers in the group. They all fall into an incredibly small percentile. Assume that the history of science encompasses 10 million papers. One percent of these would constitute a very large group of 100 thousand; 0.1% a healthy 10 thousand; and .01% would be only 1000. Thus the list which follows and the ten that dropped from the list fall into the .001 percentile. Papers #38 and 42 to 50 did not appear on the 1967 list. Not surprisingly only one of them was not published *before* 1967. This is the 1969 Weber and Osborn paper (#49) on gel electrophoresis. Ornstein's 1964 paper on disc electrophoresis is among the new papers, but it appears to have peaked with 274 citations in 1971. The Weber-Osborn paper was cited 638 times in 1972 alone. The paper by Mancini (#46) on immunochemical quantitation of antigens also has not

yet peaked; its 1972 count of 357 was up 20% from 1971.

Despite their 'age' many of the papers achieved their *highest* citation rate in 1972, and continue to rise. Lowry's paper on protein determination (with an incredible 5,245 citations), and the papers by Folch #5, Spackman #7, Gornall #9, Burton #12, Marmur #18, Bartlett #24, Warren #28, Chen #43, Mancini #46, Dulbecco #48, and Weber #49 all indicate increasing activity in those fields.

How much does a single paper contribute to the citedness of individual authors? If you compare this list of most cited *papers* with a list of most cited *authors*,<sup>2</sup> you find only nine names in common. In these nine cases the paper listed here *did* contribute substantially to its author's rank as a most-cited author. However, if these nine authors had *not* written a citation block-buster all but two of them *would still be among the 1000 scientists whose work was most cited during the 1961-1972 period*. The two exceptions are among the 6000 scientists most cited during the same period. A scientific 'flash in the pan' seems to be a rarity.

Keep in mind that this list does not include highly cited books or other 'non-journal' items.<sup>3</sup> It is interesting that several books were cited as frequently as any journal article on this list including those by Snedecor, Siegel, Pearse, Pauling, Steel, Winer, Herzberg, etc.

Clearly "methodology" predominates in the list—much of it in molecular biology and biochemistry. But doesn't this reflect the high rate of activity in those areas?

In the future I will discuss the quality of papers that rank in the "lower" percentiles, but nevertheless provide indicators of where the action is or will be in present and future research. The potential usefulness of citation data in forecasting and mapping

scientific research is the basis of work we have undertaken with support of the NSF in the exciting field of science policy analysis. By combining the preliminary indicators of citation frequency with clustering techniques<sup>4</sup> one can observe patterns of coalescence in science. I still have hopes that we can some day try the same techniques for observing the history of technology through citation analysis of patents.<sup>5</sup>

1. Garfield, E. "Citation indexing, historiography, and the sociology of science." In: *Proc. Third Internat. Congr. Med. Librarianship, Amsterdam, 5-9 May 1969*, ed. by K.E. Davis & W.D. Sweeney (Amsterdam: Excerpta Medica, 1970) p. 187-204. Reprinted in: *Current Contents* No. 15, 14 April 1971, p. M24-41.  
2. ———. More on forecasting Nobel prizes and the most cited scientists of 1972! *CC* No. 40, 3 October 1973, p. 5-7.

3. ———. A core research library for developing graduate schools: the 100 books most-cited by researchers. *CC* No. 1, 2 January 1973, p. 5-9.  
4. Small, H. Co-citation in the scientific literature: a new measure of the relationship between two documents. *J. Amer. Soc. Inf. Sci.* 24(4):265-9, 1973.  
5. Seidel, A.H. Citation system for patent office. *J. Patent Office Soc.* 31:554, 1949.

#### MOST-CITED JOURNAL ARTICLES 1961-1972.

Rank	Times Cited	Bibliographical Data
1.	29655	Lowry, O.H., Rosebrough, N.J., Farr, A.L., & Randall, R.J. Protein measurement with the Folin phenol reagent. <i>J. Biol. Chem.</i> 19(3):265-75, 1951.
2.	6281	Reynolds, E.S. The use of lead citrate at high pH as an electron opaque stain in electron microscopy. <i>J. Cell Biol.</i> 17:208-12, 1963.
3.	5825	Fiske, C.H. & Subbarow, Y. The colorimetric determination of phosphorus. <i>J. Biol. Chem.</i> 66:375-400, 1925.
4.	5273	Luft, J.H. Improvements in epoxy resin embedding methods. <i>J. Biophys. Biochem. Cytol.</i> 9:409-14, 1961.
5.	5054	Folch, J., Lees, M. & Sloane Stanley, G.H. A simple method for the isolation and purification of total lipides from animal tissues. <i>J. Biol. Chem.</i> 226:497-509, 1957.
6.	4932	Bray, G.A. A simple efficient liquid scintillator for counting aqueous solutions in a liquid scintillation counter. <i>Analyt. Biochem.</i> 1:279-85, 1960.
7.	4376	Spackman, D.H., Stein, W.H. & Moore, S. Automatic recording apparatus for use in the chromatography of amino acids. <i>Analyt. Chem.</i> 30:1190-1206, 1958.
8.	4367	Sabatini, D.D., Bensch, K. & Barnett, R.J. Cytochemistry and electron microscopy; the preservation of cellular ultrastructure and enzymatic activity by aldehyde fixation. <i>J. Cell Biol.</i> 17:19-58, 1963.
9.	3967	Gornall, A.G., Bardawill, C.J. & David, M.M. Determination of serum proteins by means of the biuret reaction. <i>J. Biol. Chem.</i> 78:751-66, 1949.
10.	3621	Lineweaver, H. & Burk, D. The determination of enzyme dissociation constants. <i>J. Am. Chem. Soc.</i> 56:658-66, 1934.

Rank	Times Cited	Bibliographical Data
11.	3464	Davis, B.J. Disc electrophoresis. 2. Method and application to human serum proteins. <i>Ann. New York Acad. Sci.</i> 121:404-27, 1964.
12.	3406	Burton, K. A study of the conditions and mechanism of the diphenylamine reaction for the colorimetric estimation of deoxyribonucleic acid. <i>Biochem. J.</i> 62:315-23, 1956.
13.	2903	Scheidegger, J.J. Une micro-methode de l'immuno-electrophorese. <i>Internat. Arch. Allergy</i> 7:103-10, 1955.
14.	2770	Duncan, D.B. Multiple range and multiple <i>F</i> tests. <i>Biometrics</i> 11:1-42, 1955.
15.	2740	Nelson, N. A photometric adaptation of the Somogyi method for the determination of glucose. <i>J. Biol. Chem.</i> 153:375-80, 1944.
16.	2620	Reed, L.J. & Muench, H. A simple method of estimating fifty per cent endpoints. <i>Amer. J. Hygiene</i> 27:493-97, 1938.
17.	2293	Dole, V.P. A relation between non-esterified fatty acids in plasma and the metabolism of glucose. <i>J. Clin. Invest.</i> 35:150-54, 1956.
18.	2230	Marmur, J. A procedure for the isolation of deoxyribonucleic acid from micro-organisms. <i>J. Mol. Biol.</i> 3:208-18, 1961.
19.	2226	Moorhead, P.S., Nowell, P.C., Mellman, W.J., Battips, D.M., & Hungerford, D.A. Chromosome preparations of leukocytes cultured from human peripheral blood. <i>Exp. Cell Res.</i> 20:613-16, 1960.
20.	2054	Warburg, O. & Christian, W. Isolierung und Kristallisation des Garungsferments Enolase. <i>Biochem. Zschr.</i> 310:384-421, 1941.
21.	1976	Jacob, F. & Monod, J. Genetic regulatory mechanisms in the synthesis of proteins. <i>J. Mol. Biol.</i> 3:318-56, 1961.
22.	1905	Martin, R.G. & Ames, B.N. A method for determining the sedimentation behavior of enzymes: application to protein mixtures. <i>J. Biol. Chem.</i> 236:1372-79, 1961.
23.	1887	Watson, M.L. Staining of tissue sections for electron microscopy with heavy metals. <i>J. Biophys. Biochem. Cytol.</i> 4:475-9, 1958.
24.	1885	Bartlett, G.R. Phosphorus assay in column chromatography. <i>J. Biol. Chem.</i> 234:466-68, 1959.
25.	1849	Palade, G.E. A study of fixation for electron microscopy. <i>J. Exp. Med.</i> 95:285-97, 1952.
26.	1841	Smithies, O. Zone electrophoresis in starch gels: group variations in the serum proteins of normal human adults. <i>Biochem. J.</i> 61:629-41, 1955.
27.	1814	Barker, S.B. & Summerson, W.H. The colorimetric determination of lactic acid in biological material. <i>J. Biol. Chem.</i> 138:535-554, 1941.
28.	1767	Warren, L. The thiobarbituric acid assay of sialic acids. <i>J. Biol. Chem.</i> 234:1971-75, 1959.
29.	1737	Trevelyan, W.E., Procter, D.P. & Harrison, J.S. Detection of sugars on paper chromatograms. <i>Nature</i> 166:444-5, 1950.
30.	1695	Dubois, M., Gilles, K.A., Hamilton, J.K., Rebers, P.A. & Smith, F. Colorimetric method for determination of sugars and related substances. <i>Analyt. Chem.</i> 28:350-56, 1956.
31.	1662	Eagle, H. Amino acid metabolism in mammalian cell cultures. <i>Science</i> 130:432-37, 1959.
32.	1628	Litchfield, J.T. Jr., & Wilcoxon, F. A simplified method of evaluating dose-effect experiments. <i>J. Pharmacol. Exp. Ther.</i> 96:99-113, 1949.
33.	1398	Ellman, G.L. Tissue sulfhydryl groups. <i>Arch. Biochem. Biophys.</i> 82:70-77, 1959.
34.	1387	Bardeen, J., Cooper, L.N. & Schrieffer, J.R. Theory of superconductivity. <i>Physical Review</i> 108:1175-1204, 1957.

Rank	Times Cited	Bibliographical Data
35.	1384	Andrews, P. Estimation of the molecular weights of proteins by Sephadex gel-filtration. <i>Biochem. J.</i> 91:222-33, 1964.
36.	1384	Schmidt, G. & Thannhauser, S.J. A method for the determination of desoxyribonucleic acid, ribonucleic acid, and phosphoproteins in animal tissues. <i>Biochem. J.</i> 161:83-9, 1945.
37.	1344	Jaffe, H.H. A reexamination of the Hammett equation. <i>Chem. Revs.</i> 53: 191-261, 1953.
*38.	1333	Venable, J.H. & Coggeshall, R. A simplified lead citrate stain for use in electron microscopy. <i>J. Cell Biol.</i> 25:407-8, 1965.
39.	1324	Karnovsky, M.J. Simple method for staining with lead at high pH in electronmicroscopy. <i>J. Biophys. Biochem. Cytol.</i> 11:729-32, 1961.
40.	1317	Karplus, M. Contact electron-spin coupling of nuclear magnetic moments. <i>J. Chem. Phys.</i> 30:11-15, 1959.
41.	1305	Gell-Mann, M. Symmetries of baryons and mesons. <i>Physical Review</i> 125: 1067-84, 1962.
*42.	1297	Ornstein, L. Disc electrophoresis. 1. Background and theory. <i>Ann. New York Acad. Sci.</i> 121:321-49, 1964.
*43.	1294	Chen, P.S. Jr., Toribara, T.Y. & Warner, H. Microdetermination of phosphorus. <i>Analyt. Chem.</i> 28:1756-58, 1956.
*44.	1292	Moore, S., Spackman, D.H. & Stein, W.H. Chromatography of amino acids on sulfonated polystyrene resins. <i>Analyt. Chem.</i> 30:1185-90, 1958.
*45.	1278	Schneider, W.C. Phosphorus compounds in animal tissues. 1. Extraction and estimation of desoxypentose nucleic acid and of pentose nucleic acid. <i>J. Biol. Chem.</i> 161:293-303, 1945.
*46.	1239	Mancini, G., Carbonara, A.O. & Heremans, J.F. Immunochemical quantitation of antigens by single radial immunodiffusion. <i>Immunochemistry</i> 2:235-54, 1965.
*47.	1226	Yphantis, D.A. Equilibrium ultracentrifugation of dilute solutions. <i>Biochemistry</i> 3:297-317, 1964.
*48.	1214	Dulbecco, R. & Vogt, M. Plaque formation and isolation of pure lines with poliomyelitis viruses. <i>J. Exp. Med.</i> 99:167-82, 1954.
*49.	1209	Weber, K. & Osborn, M. The reliability of molecular weight determinations by dodecyl sulfate-polyacrylamide gel electrophoresis. <i>J. Biol. Chem.</i> 244:4406-12, 1969.
*50.	1207	Mandell, J.D. & Hershey, A.D. A fractionating column for analysis of nucleic acids. <i>Analyt. Biochem.</i> 1:66-77, 1960.

\*These articles did not appear on a similar 1967 list of the 50 most-cited articles.