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Current Comments®

The Articles Most Cited in 1961-1982. 3. Another 100 All-Time *Citation Classics*

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In previous essays, we discussed the 200 papers most cited from 1961 through 1982 in *Science Citation Index®* (*SCI®*).[1,2] Another 100 papers in the series for this 22-year period follow. Of the millions of papers cited during this period, less than 500 papers were cited more than 1,000 times. The frequency distribution for articles cited at least 50 times between 1961 and 1982 is given in Table 1. While the average scientific paper is cited less than one time each year over a 20-year period, less than one in 10,000 will be cited over 500 times.

Although each of the papers in this study is by definition a *Citation Classic™*,[3] only 43 have been commented on by their authors in *Current Contents®* (*CC®*). As is explained in each issue of *CC* in the section devoted to their commentaries, we urge authors to provide some hindsight on their work. We invite the authors and/or coauthors of the remaining 59 high-impact papers listed below to submit *Citation Classic* commentaries. For those classic authors who are retired or deceased, we encourage colleagues to submit commentaries, even if they were not a coauthor of the paper identified. Whenever possible, authors are asked to send their essays to coauthors.

The 100 papers in this study are listed in alphabetic order by first author. We use this arrangement to discourage invidious comparisons of individual papers by citation counts alone. Full bibliographic information is given for each paper. We've also included 1983 citation counts, in parentheses, to give you an idea of how frequently these papers are currently cited. 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 follow the reference.

Four of the papers were included in a study published in 1974 covering 1961-1972.[4,5] Of the 200 articles listed in the first two parts of this series, 76 also appeared in the 1974 study.[1,2] Remarkably, 80 out of the 100 identified over ten years ago have continued to rank among the most-cited articles.

The articles were published in 54 journals. *Journal of Biological Chemistry* (*JBC*) published nine. *Physical Review* and *Nature* follow with five papers each. As expected, the majority of classic papers are concentrated in these and other high-impact journals, such as *Lancet* and *Science*.

Eleven Nobel laureates appear in Table 2—P.W. Anderson, C. de Duve, W. Gilbert, A.L. Hodgkin, B. Katz, P. Mitchell, S. Moore, M.F. Perutz, B. Samuelsson, W.H. Stein, and J.H. Van Vleck. Hodgkin received the prize for medicine in 1963 for his work on neuronal physiology. Katz was awarded the prize for medicine in 1970 for work on the chemical transmission of nerve impulses. They coauthored one of the papers in this study, published in the *Journal of Physiology* in 1949. Moore and

Table 1: Citation frequency distribution for papers cited at least 50 times in *SCI*®, 1961-1982. A = number of citations. B = number of items receiving that number of citations. C = approximate percent of items examined (n = 226,358).

A	B	C
≥ 5000	20	*
4000-4999	13	*
3000-3999	24	*
2000-2999	48	*
1000-1999	328	.1
900-999	114	.1
800-899	144	.1
700-799	209	.1
600-699	340	.1
500-599	628	.3
400-499	1182	.5
300-399	2767	1.2
200-299	8614	3.8
100-199	47,793	21.1
50-99	164,134	72.5

*equals < .05 percent of items cited at least 50 times in *SCI*, 1961-1982.

Stein, who shared the 1972 Nobel prize for chemistry, also coauthored two papers in this study. In fact, Moore has five papers among the 300 most-cited papers from 1961 to 1982.

Of the 189 authors in this study, 41 were listed among the 1,000 contemporary scientists most cited from 1965 to 1978.[6] In the first two parts of this series, 78 authors were listed. Undoubtedly, a large number of those 1,000 authors will turn up as this series is extended, but not every highly cited author produces a *Citation Classic*. Indeed, we expect to show in the future which scientists *of Nobel class* have not, for whatever reason, been associated with such a classic paper.

The distribution of publication dates for the papers in this study is shown in

Table 2. The third 100 most-cited articles, 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. A number symbol (#) indicates that the paper appeared in the 1974 list of most-cited articles.

A	B
1244 (40)	**Adelberg E A, Mandel M & Chen G C C.** Optimal conditions for mutagenesis by N-methyl-N^1-nitro-N-nitrosoguanidine in *Escherichia coli* K12. *Biochem. Biophys. Res. Commun.* 18:788-95, 1965.
1438 (39)	#***Allen R J L.** The estimation of phosphorus. *Biochem. J.* 34:858-65, 1940. (39/82/LS)
1354 (83)	**Ames B N & Dubin D T.** The role of polyamines in the neutralization of bacteriophage deoxyribonucleic acid. *J. Biol. Chem.* 235:769-75, 1960.
1313 (95)	***Aminoff D.** Methods for the quantitative estimation of *N*-acetylneuraminic acid and their application to hydrolysates of sialomucoids. *Biochem. J.* 81:384-92, 1961. (26/80/LS)
1400 (75)	**Anderson P W.** Localized magnetic states in metals. *Phys. Rev.* 124:41-53, 1961.
1295 (75)	**Anson M L.** The estimation of pepsin, trypsin, papain, and cathepsin with hemoglobin. *J. Gen. Physiol.* 22:79-89, 1938.
1361 (63)	**Avrameas S & Ternynck T.** The cross-linking of proteins with glutaraldehyde and its use for the preparation of immunoadsorbents. *Immunochemistry* 6:53-66, 1969.
1232 (32)	***Bachmann B J, Low K B & Taylor A L.** Recalibrated linkage map of *Escherichia coli* K-12. *Bacteriol. Rev.* 40:116-67, 1976. (8/82/LS)
1302 (69)	***Barka T & Anderson P J.** Histochemical methods for acid phosphatase using hexazonium pararosanilin as coupler. *J. Histochem. Cytochem.* 10:741-53, 1962. (8/78)
1440 (184)	***Berry M N & Friend D S.** High-yield preparation of isolated rat liver parenchymal cells. *J. Cell Biol.* 43:506-20, 1969. (3/84/LS)
1305 (50)	***Blanco C, Patrick R & Nussenzweig V.** A population of lymphocytes bearing a membrane receptor for antigen-antibody-complement complexes. *J. Exp. Med.* 132:702-20, 1970. (20/81/LS)
1264 (91)	**Black J W, Duncan W A M, Durant C J, Ganellin C R & Parsons E M.** Definition and antagonism of histamine H_2-receptors. *Nature* 236:385-90, 1972.
1419 (34)	#**Boas N F.** Method for the determination of hexosamines in tissues. *J. Biol. Chem.* 204:553-63, 1953.
1295 (33)	**Brecher G & Cronkite E P.** Morphology and enumeration of human blood platelets. *J. Appl. Physiol.* 3:365-77, 1950.

1263 (14) **#Caulfield J B.** Effects of varying the vehicle for OsO_4 in tissue fixation. *J. Biophys. Biochem. Cytol.* 3:827-9, 1957.

1462 (56) ***Cleland W W.** The kinetics of enzyme-catalyzed reactions with two or more substrates or products. I. Nomenclature and rate equations. *Biochim. Biophys. Acta* 67:104-37, 1963. (28/77)

1255 (439) **Cleveland D W, Fischer S G, Kirschner M W & Laemmli U K.** Peptide mapping by limited proteolysis in sodium dodecyl sulfate and analysis by gel electrophoresis. *J. Biol. Chem.* 252:1102-6, 1977.

1332 (83) **Cooley J W & Tukey J W.** An algorithm for the machine calculation of complex Fourier series. *Math. Comput.* 19:297-301, 1965.

1377 (152) ***Cunningham A J & Szenberg A.** Further improvements in the plaque technique for detecting single antibody-forming cells. *Immunology* 14:599-600, 1968. (50/81/LS)

1295 (118) **Dahlstrom A & Fuxe K.** Evidence for the existence of monoamine-containing neurons in the central nervous system. *Acta Physiol. Scand.* 62(Suppl.232):1-55, 1964.

1459 (43) **de Duve C & Wattiaux R.** Functions of lysosomes. *Annu. Rev. Physiol.* 28:435-92, 1966.

1413 (312) ***Denhardt D T.** A membrane-filter technique for the detection of complementary DNA. *Biochem. Biophys. Res. Commun.* 23:641-6, 1966. (43/82/LS)

1271 (44) **Dische Z & Shettles L B.** A specific color reaction of methylpentoses and a spectrophotometric micromethod for their determination. *J. Biol. Chem.* 175:595-603, 1948.

1291 (63) **Dittmer J C & Lester R L.** A simple, specific spray for the detection of phospholipids on thin-layer chromatograms. *J. Lipid Res.* 5:126-7, 1964.

1196 (74) ***Doyle P A & Turner P S.** Relativistic Hartree-Fock X-ray and electron scattering factors. *Acta Crystallogr. A* 24:390-7, 1968. (29/80/ET&AS)

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1212 (56) **Fink R P & Heimer L.** Two methods for selective silver impregnation of degenerating axons and their synaptic endings in the central nervous system. *Brain Res.* 4:369-74, 1967.

1252 (100) **Fletcher R & Powell M J D.** A rapidly convergent descent method for minimization. *Comput. J.* 6:163-8, 1963.

1188 (51) ***Frank H S & Evans M W.** Free volume and entropy in condensed systems. III. Entropy in binary liquid mixtures; partial molal entropy in dilute solutions; structure and thermodynamics in aqueous electrolytes. *J. Chem. Phys.* 13:507-32, 1945. (50/83/PC&ES)

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1193 (32) ***Fredrickson D S, Levy R I & Lees R S.** Fat transport in lipoproteins—an integrated approach to mechanisms and disorders. Type IV hyperlipoproteinemia. *N. Engl. J. Med.* 276:273-81, 1967. (3/78)

1430 (96) ***Glashow S L, Iliopoulos J & Maiani L.** Weak interactions with lepton-hadron symmetry. *Phys. Rev. D—Part. Fields* 2:1285-92, 1970. (20/80/PC&ES)

1283 (47) ***Goodwin T W & Morton R A.** The spectrophotometric determination of tyrosine and tryptophan in proteins. *Biochem. J.* 40:628-32, 1946. (28/81/LS)

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1371 (179) ***Hamberg M, Svensson J & Samuelsson B.** Thromboxanes: a new group of biologically active compounds derived from prostaglandin endoperoxides. *Proc. Nat. Acad. Sci. US* 72:2994-8, 1975. (2/83/LS)

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Table 3: Chronological distribution of publication dates of the third 100 most-cited articles. A = publication years. B = number of papers.

A	B
1920s	1
1930s	1
1940s	13
1950s	19
1960s	46
1970s	19
1980s	1

Table 3. This is similar to the distribution of publication dates for the 200 most-cited articles. The oldest paper in this segment of the study, published in 1924 in *JBC*, is the classic method by D.D. Van Slyke and J.M. Neill for measuring blood gases. The paper was explicitly cited 17 times in 1983, mainly in clinical journals, indicating that clinical researchers still feel compelled to cite this 60-year-old method.

The most recent paper, by A.M. Maxam and W. Gilbert, was published in *Methods in Enzymology* in 1980. That same year, Gilbert won the Nobel prize for chemistry for his work on the structure of DNA. Their paper on a technique for sequencing DNA received 56 citations in 1980, 387 in 1981, 766 in 1982, and 1,085 in 1983. Clearly, this method attracted immediate attention and has been widely and increasingly used, demonstrating the extensive impact of an important methodology.

We have commented in the first two parts of this series on the dominance of methods papers in citation-based studies. Methods papers describe strategies for studying a particular research problem. Highly cited methods papers represent frequently or widely used strategies, "tried and true" techniques. That is, they can be cited steadily over a long period of time in the literature of such "small" fields as surgery or mathematics. Or they can be cited in the tens of thousands of biochemical articles published each year and achieve high impact in a relatively short time. In any case, while many well-cited methods are regarded as less than ingenious, others like the Maxam and Gilbert paper represent innovations of the highest caliber.

Although many methods papers turn out to be highly cited, they are often undervalued by researchers and journal editors. Yoram Salomon, Weizmann Institute of Science, Rehovot, Israel, discussed the difficulties he and his colleagues had in writing and publishing their classic method for assaying the enzyme adenylate cyclase. In a *Citation Classic* commentary, Salomon said, "We consulted other colleagues who advised us not to waste time on a methods paper. Nevertheless, we could not avoid the feeling that many would welcome an efficient new method.... In its present form, the paper was initially rejected for insufficient advancement. However, our persistence with the editor resulted in its acceptance."[7] The paper has been explicitly cited over 1,500 times since it was published in 1974.

The potential economic value of certain scientific techniques has intensified interest in methods papers. For example, the growth of the genetic engineering industry has had an impact on the citation of pure and applied genetics research. David T. Denhardt, University of Western Ontario, Canada, devised a technique for detecting complementary DNA sequences. In a commentary on this 1966 paper, Denhardt said, "Despite the reprint requests, I saw very few applications of this technique until recombinant DNA technology came into use."[8] The paper was cited 139 times in 1966-1970, 232 in 1971-1975, 546 in 1976-1980, and 808 times in 1981-1983.

Of course, many theoretical works are listed. A characteristic of these high-impact conceptual works is that they raise more questions than they answer. That is, their ideas have consequences for researchers in related fields and initiate further investigations. Mats Hamberg, Karolinska Institutet, Stockholm, Sweden, makes this point in a commentary on the 1975 paper he wrote with Jan

Svensson and recent Nobel laureate Samuelsson. He said, "[It was] the first example of physiological and pathological roles for the prostaglandin-thromboxane system in man.... [This] finding ...has stimulated a large number of biochemical, physiological, and clinical studies."[9]

Relevant reviews of the literature may prove to be highly cited. These papers provide a useful function in defining the consensus of scientific research on a particular topic. By providing such overviews, these papers can provoke fresh insights into the problem. For example, Philip Seeman, University of Toronto, Canada, reviewed the actions of anesthetics and tranquilizers on cell membranes. In a commentary on this 1972 review, Seeman said, "The importance of the review is that it correlates the membrane effects with drug concentrations.... The further reaching importance is that the review prompted the subsequent discovery that alcohol-tolerant tissues have membranes that are more resistant to fluidization by ethanol."[10]

Although the majority of articles in this series come from the life sciences, 19 of the 100 articles listed in Table 2 are from the physical sciences. This is an increase of seven from the first segment of this study, and is equal to the number found in the second segment. As this study is extended, we may see an increase in the number of papers from the physical sciences.

In the weeks to come, we'll continue this series and list additional groups of *Citation Classics*. So far, we've identified 300 papers cited at least 1,188 times from 1961 to 1982. The data in Table 1 show that we can continue this particular series almost indefinitely if we define a *Citation Classic* as any paper cited over 300 times. By the time we would have published 5,000 titles, it would be necessary to resort the file so that we could include the new crop of classics. This would be in addition to those papers we identify by different criteria so that we do not ignore the smaller fields.

* * * * *

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