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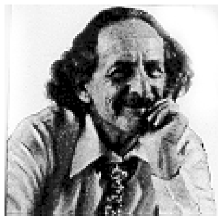

Current Comments®

The 100 Most-Cited Papers Ever and How We Select *Citation Classics*

Number 23 June 4, 1984

Each week for the past seven and a half years, we have published in *Current Contents*® (*CC*®) personal commentaries by authors of *Citation Classics*™.[1,2] In these commentaries, authors of high-impact work discuss the roles they and their coworkers played in the evolution of their milestone papers and books. They also offer opinions on why their work proved important. We have now published more than 1,800 of these commentaries.

We are often asked how these commentaries are selected. Ideally, we would like to have published a commentary for every highly cited classic—certainly those among the top thousand. We would also want a fairly even representation of the classics from each major discipline or research specialty. In reality, however, a number of pragmatic considerations prevent us from achieving the ideal. This is an important point to keep in mind.

Citation Classics have been the basis for at least one study of scientific productivity. For example, E.O. Schulz-DuBois recently published an interesting analysis of the *Citation Classics* published by German scientists.[3] While his conclusions about the quality of research in postwar Germany may be valid, we cannot be sure that our "sampling" is random. It is quite possible that we might have selected more foreign scientists had we emphasized selection by journal on a country-by-country basis. I hope we have been unbiased, but in reviewing our selections to date we certainly could not claim that each country is adequately represented.

The fact is that we use citation frequency as the first criterion in selecting *Citation Classics* candidates. This almost invariably leads to articles published in the well-known international journals. As reported earlier, we have identified about 2,000 papers cited over 500 times in *Science Citation Index*® (*SCI*®). Table 1 provides a frequency distribution for articles cited between 1961 and 1980.

We have invited most of the first authors of the 1,000 most-cited papers to write commentaries. About 40 percent of them have done so. A small percentage have explicitly refused our invitations. However, we don't know how many simply failed to receive our invitations. Many authors moved long before our invitations were mailed. Occasionally, we used the address provided on the original paper. Many authors have died or are in retirement. One of my own professors, now 90, wrote that he no longer writes papers. We are systematically attempting to send invitations to coauthors, or other colleagues who might be in a position to comment on the highly cited work. This essay, and new letters we are sending out, are intended to facilitate location of at least one qualified commentator.

The 100 most-cited papers for the period 1961-1982 are provided in Table 2. The asterisks indicate those papers that have been featured as *Citation Classics*. If you are an author of one of the "missing" papers, please consider this an open invitation to write a commentary. If you were a colleague of any of the deceased authors, and if you are willing and able to write 500 words about the topic, please contact me. The benefits to students, historians, and others would be significant. These commentaries provide insights into the process of discovery that cannot be obtained by simply reading the original papers.

In future essays, we will catalog the additional candidates for *Citation*

Table 1: Citation frequency distribution for papers in *SCI*®, 1961-1980. A=number of citations. B=approximate number of items receiving that number of citations. C=approximate percent of the entire *SCI* file.

A	B	C
>5000	20	*
4000-4999	11	*
3000-3999	25	*
2000-2999	44	*
1000-1999	334	*
500-999	1500	*
100-499	54,000	.3
50-99	145,000	.7
25-49	393,000	2.0
15-24	558,000	2.9
10-14	656,000	3.4
5-9	1,690,000	8.8
2-4	4,562,000	23.7
1	11,228,000	58.2
	19,287,934	

*equals <.01 percent of total *SCI* file, 1961-1980.

Classics. While any paper cited over 400 times will probably qualify, citation frequencies will vary from field to field. A paper from the *Journal of Symbolic Logic* that has been cited over 50 times is a classic for that small field. This does not prevent superstar papers in small fields that have wide multidisciplinary impact. Commentaries on a well-cited review paper in even a relatively small discipline may tell the rest of us much about the early development of that field.

To facilitate selection of candidates, we have created many files at ISI®. One file provides a list of about 200,000 papers that have been cited over 50 times. For many high-impact journals, that threshold is quite low. Since these are frequency-ranked lists, the number of papers in each rank for a particular journal can tell us something about its size and just how unusual the citation frequency is.

In recent times, we have accumulated multi-year impact data on most journals. These data confirm that the lifetime citation expectancy of articles in certain journals will exceed 100 citations.[4] Articles published in the *Proceedings of the National Academy of Sciences* (*PNAS*), will reach that figure after 20 years. In fact 2,400 papers from *PNAS* have already been cited more than 100 times.

In order to obtain as wide a representation of journals as possible, we made a concerted effort to obtain commentaries for the most-cited paper in each specialty journal. As a result of this policy, we have identified hundreds of "small field" papers and journals. Unless we did this, papers from the superstar journals would predominate. While we could easily have justified selecting many more, we have so far published only 30-35 classics from journals like *PNAS*, *Science*, *Journal of the American Chemical Society*, *Lancet*, *Psychological Reviews*, etc.

Table 3 provides a partial list of the more than 500 journals that have been represented in *Citation Classics* to date. Space considerations forced us to limit this list to those represented by three or more commentaries. Thus, it includes many well-known, superstar journals. However, this almost defeats the point of the listing, which is intended to show that small fields are represented by journals such as *Nursing Research*, *Economic Geology*, and *Public Administration Review*.

A key factor which has tended to distort journal and field representation is the arbitrary decision to treat the articles published in journals covered in each *CC* edition as a "separate" population of papers. By publishing one classic each week in *CC/Agriculture, Biology & Environmental Sciences*, we in fact have an overrepresentation from plant science. Considering the number of papers published in biochemistry and other life sciences, we could easily justify four or more *Citation Classics* in *CC/Life Sciences* (*CC/LS*) each week. Similarly, the distribution for *CC/Engineering, Technology & Applied Sciences* and *CC/Physical, Chemical & Earth Sciences* (*CC/PC&ES*) is distorted. In order to reduce this bias, we recently reduced the number of engineering papers. This has irritated some readers. In addition, we found that it was difficult to convince engineering scientists to write about their classic papers. Furthermore, in engineering, as in the social sciences, books rather than journal articles are often the classic or primordial publications. Even a few technical reports surfaced, as would patents if we searched for them.

When I first read the Schulz-DuBois paper,[3] I found it hard to believe that more papers from *Chemische Berichte*

Table 2: The 100 most-cited *SCI*® articles listed in alphabetical order by first author. An asterisk (*) indicates that the paper was featured as a *Citation Classic*™ in *Current Contents*® (*CC*®). The issue number, year, and edition of *CC* in which the classic appeared are indicated in parentheses. (In 1977 and 1978, the same *Citation Classic* was featured in each edition of *CC*.) Two asterisks (**) indicate that the paper did not appear on the 1974 list of most-cited articles.

Citations	Bibliographic Data
2286 **	***Ames B N, McCann J & Yamasaki E.** Methods for detecting carcinogens and mutagens with the salmonella/mammalian-microsome mutagenicity test. *Mutat. Res.* 31:347-64, 1975. (12/84/LS)
3533	**Andrews P.** Estimation of the molecular weights of proteins by sephadex gel-filtration. *Biochem. J.* 91:222-33, 1964.
2535 **	**Andrews P.** The gel-filtration behaviour of proteins related to their molecular weights over a wide range. *Biochem. J.* 96:595-606, 1965.
3921	**Arnon D I.** Copper enzymes in isolated chloroplasts. Polyphenoloxidase in *Beta vulgaris*. *Plant Physiol.* 24:1-15, 1949.
2161	**Bardeen J, Cooper L N & Schrieffer J R.** Theory of superconductivity. *Phys. Rev.* 108:1175-204, 1957.
2489	***Barker S B & Summerson W H.** The colorimetric determination of lactic acid in biological material. *J. Biol. Chem.* 138:535-54, 1941. (46/83/LS)
5772	**Bartlett G R.** Phosphorus assay in column chromatography. *J. Biol. Chem.* 234:466-8, 1959.
2342 **	**Bitter T & Muir H M.** A modified uronic acid carbazole reaction. *Anal. Biochem.* 4:330-4, 1962.
5117	***Bligh E G & Dyer W J.** A rapid method of total lipid extraction and purification. *Can. J. Biochem. Physiol.* 37:911-7, 1959. (52/78)
3911 **	***Bonner W M & Laskey R A.** A film detection method for tritium-labelled proteins and nucleic acids in polyacrylamide gels. *Eur. J. Biochem.* 46:83-8, 1974. (1/83/LS)
8654 **	***Boyum A.** Isolation of mononuclear cells and granulocytes from human blood. *Scand. J. Clin. Lab. Inv.* 21(Suppl.):77-89, 1968. (45/82/LS)
4550 **	**Bradford M M.** A rapid and sensitive method for the quantitation of microgram quantities of protein utilizing the principle of protein-dye binding. *Anal. Biochem.* 72:248-54, 1976.
2114	**Bratton A C & Marshall E K.** A new coupling component for sulfanilamide determination. *J. Biol. Chem.* 128:537-50, 1939.
9305	***Bray G A.** A simple efficient liquid scintillator for counting aqueous solutions in a liquid scintillation counter. *Anal. Biochem.* 1:279-85, 1960. (2/77)
9803	***Burton K.** A study of the conditions and mechanism of the diphenylamine reaction for the colorimetric estimation of deoxyribonucleic acid. *Biochem. J.* 62:315-22, 1956. (26/77)
3809	***Chen P S, Toribara T Y & Warner H.** Microdetermination of phosphorus. *Anal. Chem.* 28:1756-8, 1956. (9/77)
3090 **	***Conney A H.** Pharmacological implications of microsomal enzyme induction. *Pharmacol. Rev.* 19:317-66, 1967. (3/79/LS)
2419 **	**Cromer D T.** Anomalous dispersion corrections computed from self-consistent field relativistic Dirac-Slater wave functions. *Acta Crystallogr.* 18:17-23, 1965.
2325 **	**Cromer D T & Liberman D.** Relativistic calculation of anomalous scattering factors for X-rays. *J. Chem. Phys.* 53:1891-8, 1970.
3464 **	**Cromer D T & Mann J B.** X-ray scattering factors computed from numerical Hartree-Fock wave functions. *Acta Crystallogr. A* 24:321-5, 1968.
3464	**Cromer D T & Waber J T.** Scattering factors computed from relativistic Dirac-Slater wave functions. *Acta Crystallogr.* 18:104-9, 1965.
2043 **	***Cuatrecasas P.** Protein purification by affinity chromatography. *J. Biol. Chem.* 245:3059-65, 1970. (22/80/LS)
13,222	**Davis B J.** Disc electrophoresis—II. Method and application to human serum proteins. *Ann. NY Acad. Sci.* 121:404-27, 1964.
2255	***de Duve C, Pressman B C, Gianetto R, Wattiaux R & Appelmans F.** Tissue fractionation studies. 6. Intracellular distribution patterns of enzymes in rat-liver tissue. *Biochem. J.* 60:604-17, 1955. (12/77)
3379	**Dole V P.** A relation between non-esterified fatty acids in plasma and the metabolism of glucose. *J. Clin. Invest.* 35:150-4, 1956.
6052	**Dubois M, Gilles K A, Hamilton J K, Rebers P A & Smith F.** Colorimetric method for determination of sugars and related substances. *Anal. Chem.* 28:350-6, 1956.
2580	**Dulbecco R & Vogt M.** Plaque formation and isolation of pure lines with poliomyelitis viruses. *J. Exp. Med.* 99:167-82, 1954.
6013	***Duncan D B.** Multiple range and multiple *F* tests. *Biometrics* 11:1-42, 1955. (4/77)
3448	***Eagle H.** Amino acid metabolism in mammalian cell cultures. *Science* 130:432-7, 1959. (5/77)
4287	**Ellman G L.** Tissue sulfhydryl groups. *Arch. Biochem. Biophys.* 82:70-7, 1959.
2591 **	***Ellman G L, Courtney K D, Andres V & Featherstone R M.** A new and rapid colorimetric determination of acetylcholinesterase activity. *Biochem. Pharmacol.* 7:88-95, 1961. (22/77)
4737 **	**Fairbanks G, Steck T L & Wallach D F H.** Electrophoretic analysis of the major polypeptides of the human erythrocyte membrane. *Biochemistry—USA* 10:2606-17, 1971.
11,162	**Fiske C H & Subbarow Y.** The colorimetric determination of phosphorus. *J. Biol. Chem.* 66:375-400, 1925.
13,974	**Folch J, Lees M & Sloane Stanley G H.** A simple method for the isolation and purification of total lipides from animal tissues. *J. Biol. Chem.* 226:497-509, 1957.
3019 **	**Germain G, Main P & Woolfson M M.** The application of phase relationships to complex structures. III. The optimum use of phase relationships. *Acta Crystallogr. A* 27:368-76, 1971.
3669 **	**Gilman A G.** A protein binding assay for adenosine 3':5'-cyclic monophosphate. *Proc. Nat. Acad. Sci. US* 677:305-12, 1970.
8777	***Gornall A G, Bardawill C J & David M M.** Determination of serum proteins by means of the biuret reaction. *J. Biol. Chem.* 177:751-66, 1949. (13/79/LS)

Citations	Bibliographic Data
3927 ••	**Graham R C & Karnovsky M J.** The early stages of absorption of injected horseradish peroxidase in the proximal tubules of mouse kidney: ultrastructural cytochemistry by a new technique. *J. Histochem. Cytochem.* 14:291-302, 1966.
4875 ••	***Greenwood F C, Hunter W M & Glover J S.** The preparation of ^{131}I-labelled human growth hormone of high specific radioactivity. *Biochem. J.* 89:114-23, 1963. (15/77)
2590	***Hales C N & Randle P J.** Immunoassay of insulin with insulin-antibody precipitate. *Biochem. J.* 88:137-46, 1963. (49/80/LS)
2225 ••	**Hamburger V & Hamilton H L.** A series of normal stages in the development of the chick embryo. *J. Morphol.* 88:49-92, 1951.
2074	**Higgins G M & Anderson R M.** Experimental pathology of the liver. I. Restoration of the liver of the white rat following partial surgical removal. *Arch. Pathol.* 12:186-202, 1931.
2264 ••	***Hodgkin A L & Huxley A F.** A quantitative description of membrane current and its application to conduction and excitation in nerve. *J. Physiol.—London* 117:500-44, 1952. (28/81/LS)
2203	**Hoffmann R.** An extended Huckel theory. I. Hydrocarbons. *J. Chem. Phys.* 39:1397-412, 1963.
3838 ••	**Hunter W M & Greenwood F C.** Preparation of iodine-131 labelled human growth hormone of high specific activity. *Nature* 194:495-6, 1962.
2690	**Jacob F & Monod J.** Genetic regulatory mechanisms in the synthesis of proteins. *J. Mol. Biol.* 3:318-56, 1961.
2239	***Jaffe H H.** A reexamination of the Hammet equation. *Chem. Rev.* 53:191-261, 1953. (33/77)
2507 ••	**Jondal M, Holm G & Wigzell H.** Surface markers on human T and B lymphocytes. I. A large population of lymphocytes forming nonimmune rosettes with sheep red blood cells. *J. Exp. Med.* 136:207-15, 1972.
2208 ••	**Julius M H, Simpson E & Herzenberg L A.** A rapid method for the isolation of functional thymus-derived murine lymphocytes. *Eur. J. Immunol.* 3:645-9, 1973.
4101	**Karnovsky M J.** A formaldehyde-glutaraldehyde fixative of high osmolality for use in electron microscopy. *J. Cell Biol.* 27:137A-8A, 1965.
2075	**Karplus M.** Contact electron-spin coupling of nuclear magnetic moments. *J. Chem. Phys.* 30:11-5, 1959.
2572 ••	***Krebs H A & Henseleit K.** Untersuchungen uber die Harnstoffbildung im Tierkorper. (Studies on urea formation in the animal organism.) *Hoppe-Seylers Z. Physiol. Chem.* 210:33-66, 1932. (52/80/LS)
16,872 ••	**Laemmli U K.** Cleavage of structural proteins during the assembly of the head of bacteriophage T4. *Nature* 227:680-5, 1970.
2164 ••	***Laskey R A & Mills A D.** Quantitative film detection of ^{3}H and ^{14}C in polyacrylamide gels by fluorography. *Eur. J. Biochem.* 56:335-41, 1975. (13/83/LS)
2391 ••	***Laurell C-B.** Quantitative estimation of proteins by electrophoresis in agarose gel containing antibodies. *Anal. Biochem.* 15:45-52, 1966. (51/80/LS)
2268 ••	**Layne E.** Spectrophotometric and turbidimetric methods for measuring proteins. *Meth. Enzymology* 3:447-9, 1957.
6772	**Lineweaver H & Burk D.** The determination of enzyme dissociation constants. *J. Amer. Chem. Soc.* 56:658-66, 1934.
4143	***Litchfield J T & Wilcoxon F A.** A simple method of evaluating dose-effect experiments. *J. Pharmacol. Exp. Ther.* 96:99-113, 1949. (7/77)
100,639	***Lowry O H, Rosebrough N J, Farr A L & Randall R J.** *Protein measurement with the Folin phenol reagent. J. Biol. Chem.* 193:265-75, 1951. (1/77)
9480	***Luft J H.** Improvements in epoxy resin embedding methods. *J. Biophys. Biochem. Cytol.* 9:409-14, 1961. (20/77)
6793	**Mancini G, Carbonara A O & Heremans J F.** Immunochemical quantitation of antigens by single radial immunodiffusion. *Immunochemistry* 2:235-54, 1965.
4862	**Marmur J.** A procedure for the isolation of deoxyribonucleic acid from micro-organisms. *J. Mol. Biol.* 3:208-18, 1961.
4469	**Martin R G & Ames B N.** A *method for determining the sedimentation behaviour of enzymes:* application to protein mixtures. *J. Biol. Chem.* 236:1372-9, 1961.
2522 ••	**Maxam A M & Gilbert W.** A new method for sequencing DNA. *Proc. Nat. Acad. Sci. US* 74:560-4, 1977.
2850	**Monod J, Wyman J & Changeux J P.** On the nature of allosteric transitions: a plausible model. *J. Mol. Biol.* 12:88-118, 1965.
2139 ••	**Moore S.** On the determination of cystine as cysteic acid. *J. Biol. Chem.* 238:235-7, 1963.
3456	***Moorhead P S, Nowell P C, Mellman W J, Battips D M & Hungerford D A.** Chromosome preparations of leukocytes cultured from human peripheral blood. *Exp. Cell Res.* 20:613-6, 1960. (7/83/LS)
2610 ••	***Murashige T & Skoog F.** A revised medium for rapid growth and bioassays with tobacco tissue cultures. *Physiol. Plant.* 15:473-97, 1962. (43/78)
2083 ••	***Murphy B E P.** Some studies of the protein-binding of steroids and their application to the routine micro and ultramicro measurement of various steroids in body fluids by competitive protein-binding radioassay. *J. Clin. Endocrinol. Metab.* 27:973-90, 1967. (3/81/LS)
4485 ••	***Nelson N.** A photometric adaptation of the Somogyi method for the determination of glucose. *J. Biol. Chem.* 153:375-80, 1944. (3/77)
3178 ••	***O'Farrell P H.** High resolution two-dimensional electrophoresis of proteins. *J. Biol. Chem.* 250:4007-21, 1975. (51/82/LS)
3236 ••	**Omura T & Sato R.** The carbon monoxide-binding pigment of liver microsomes. I. Evidence for its hemoprotein nature. *J. Biol. Chem.* 239:2370-8, 1964.
3414	**Ornstein L.** Disc electrophoresis—I. Background and theory. *Ann. NY Acad. Sci.* 121:321-49, 1964.
2333 ••	**Ouchterlony O.** Diffusion-in-gel methods for immunological analysis. *Progr. Allergy* 5:1-78, 1958.
2369	**Palade G E.** A study of fixation for electron microscopy. *J. Exp. Med.* 95:285-97, 1952.
4706	**Reed L J & Muench H.** A simple method of estimating 50 percent endpoints. *Amer. J. Hyg.* 27:493-7, 1938.

Citations	Bibliographic Data
2058 ••	*Reisfeld R A, Lewis U J & Williams D E.** Disk electrophoresis of basic proteins and peptides on polyacrylamide gels. *Nature* 195:281-3, 1962. (6/81/LS)
13,907	***Reynolds E S.** The use of lead citrate at high pH as an electron-opaque stain in electron microscopy. *J. Cell Biol.* 17:208-12, 1963. (32/81/LS)
3941	**Sabatini D D, Bensch K, Barrnett R J.** Cytochemistry and electron microscopy. *J. Cell Biol.* 17:19-58, 1963.
6985 ••	**Scatchard G.** The attractions of proteins for small molecules and ions. *Ann. NY Acad. Sci.* 51:660-72, 1949.
4755	**Scheidegger J J.** Une micro-methode de l'immuno-electrophorese. (A micro-method for immunoelectrophoresis.) *Int. Arch. Allergy* 7:103-10, 1955.
2416	**Schmidt G & Thannhauser S J.** A method for the determination of deoxyribonucleic acid, ribonucleic acid, and phosphoproteins in animal tissues. *J. Biol. Chem.* 161:83-9, 1945.
3046	**Shapiro A L, Vinuela E & Maizel J V.** Molecular weight estimation of polypeptide chains by electrophoresis in SDS-polyacrylamide gels. *Biochem. Biophys. Res. Commun.* 28:815-26, 1967.
2966 ••	***Singer S J & Nicolson G L.** The fluid mosaic model of the structure of cell membranes. *Science* 175:720-31, 1972. (46/77)
2513	**Smithies O.** Zone electrophoresis in starch gels: group variations in the serum proteins of normal human adults. *Biochem. J.* 61:629-41, 1955.
2295	**Somogyi M.** Notes on sugar determination. *J. Biol. Chem.* 195:19-23, 1952.
3941 ••	**Southern E M.** Detection of specific sequences among DNA fragments separated by gel-electrophoresis. *J. Mol. Biol.* 98:503, 1975.
8813	**Spackman D H, Stein W H & Moore S.** Automatic recording apparatus for use in the chromatography of amino acids. *Anal. Chem.* 30:1190-206, 1958.
4526 ••	***Spurr A R.** A low-viscosity epoxy resin embedding medium for electron microscopy. *J. Ultrastruct. Res.* 26:31-43, 1969. (50/79/LS)
5657 ••	***Stewart R F, Davidson E R & Simpson W T.** Coherent x-ray scattering for the hydrogen atom in the hydrogen molecule. *J. Chem. Phys.* 42:3175-87, 1965. (48/77)
2155 ••	**Studier F W.** Sedimentation studies of the size and shape of DNA. *J. Mol. Biol.* 11:373-90, 1965.
3276	***Trevelyan W E, Procter D P & Harrison J S.** Detection of sugars on paper chromatograms. *Nature* 166:444-5, 1950. (6/77)
2556 ••	***Vane J R.** Inhibition of prostaglandin synthesis as a mechanism of action for aspirin-like drugs. *Nature New Biol.* 231:232-5, 1971. (42/80/LS)
3487	***Venable J H & Coggeshall R.** A simplified lead citrate stain for use in electron microscopy. *J. Cell Biol.* 25:407-8, 1965. (10/77)
2302	**Warburg O & Christian W.** Isolierung und Kristallisation des Garungsferments Enolase. (Isolation and crystallization of the enzyme enolase.) *Biochem. Z.* 310:384-421, 1941.
4742	***Warren L.** The thiobarbituric acid assay of sialic acids. *J. Biol. Chem.* 234:1971-5, 1959. (36/77)
3308	**Watson M L.** Staining of tissue sections for electron microscopy with heavy metals. *J. Biophys. Biochem. Cytol.* 4:475-8, 1958.
15,189	**Weber K & Osborn M.** The reliability of molecular weight determinations by dodecyl sulfate-polyacrylamide gel electrophoresis. *J. Biol. Chem.* 244:4406-12, 1969.
2428 ••	**Weinberg S.** A model of leptons. *Phys. Rev. Lett.* 19:1264-6, 1967.
2772	**Yphantis D A.** Equilibrium ultracentrifugation of dilute solutions. *Biochemistry—USA* 3:297-317, 1964.

and other German journals did not qualify. But clearly, the heyday of the *Berichte* was in the years before World War II. Undoubtedly, had we been able to gain access to our 1955-1964 data much sooner, we would have identified many more German papers of earlier vintage.

Table 4 lists the publication dates by decade of the 100 most-cited papers. Now that the 1955-1964 *SCI* has been published, we can identify many of the earlier classics. Although, in some cases, 40 years have passed since original publication, we hope many of the authors will still be available for comment. If not, we may solicit a commentary from a colleague as we did in the case of Karl G. Jansky's paper in *Proceedings of the IRE*.[5,6]

Contrary to widespread belief, the most-cited paper in a particular specialty does not always turn up in a specialist journal. The primordial articles in many specialties will turn up in a multidisciplinary journal like *Nature* or *Science*, or in some general medical journal such as *New England Journal of Medicine* or *Lancet*. Having selected a highly cited paper in a specialist journal, we often find that the author mentions another paper that is clearly the primordial one for that topic. While the commentary submitted concerns the most-cited paper in the leading journal of its field, it would not be fair to ignore other important papers, often cited more frequently, which appeared in another journal. In such cases, we invite the author of the other important paper to write a commentary. We have found that the authors themselves often prevent unfair selection because we encourage them to mention those papers that had an impor-

Table 3: Journals represented by three or more *Citation Classics*™, in alphabetical order by journal. A = journal title. B = total number of *Citation Classics*.

A	B
Acta Chem. Scand.	3
Acta Crystallogr.	8
Acta Metall.	12
Acta Physiol. Scand.	4
Advan. Agron.	3
Advan. Ecol. Res.	3
Advan. Insect Physiol.	3
Advan. Phys.	6
Advan. Prot. Chem.	8
AIChE J.	5
Amer. Econ. Rev.	3
Amer. J. Bot.	8
Amer. J. Cardiol.	6
Amer. J. Clin. Nutr.	4
Amer. J. Clin. Pathol.	7
Amer. J. Hyg.	3
Amer. J. Med.	17
Amer. J. Obstet. Gynecol.	7
Amer. J. Pathol.	4
Amer. J. Psychiat.	4
Amer. Naturalist	10
Amer. Psychol.	7
Amer. Sociol. Rev	14
Anal. Biochem.	7
Anal. Chem.	9
Anesthesiology	3
Anim. Behav.	3
Ann. Intern. Med.	7
Ann. Math.	4
Ann. Surg.	3
Annu. Rev. Biochem.	3
Annu. Rev. Entomol.	5
Annu. Rev. Plant Physiol.	20
Appl. Opt.	3
Arch. Biochem. Biophys.	7
Arch. Dis. Child.	4
Arch. Gen. Psychiat.	8
Arch. Hydrobiol.	3
Aust. J. Exp. Biol. Med. Sci.	5
Behav. Res. Ther.	4
Bell Syst. Tech. J.	17
Biochem. Biophys. Res. Commun.	4
Biochem. J.	21
Biochem. Pharmacol.	3
Biochemistry—USA	7
Biochim. Biophys. Acta	8
Biometrics	6
Biometrika	6
Blood	7
Bot. Rev.	5
Brit. J. Exp. Pathol.	4
Brit. J. Haematol.	4
Brit. J. Psychiat.	8
Brit. Med. J.	6
Can. J. Chem.	3
Cancer	4
Cancer Res.	12
Carbohyd. Res.	4
Chem. Eng. Sci.	10
Chem. Ind. London	4
Chem. Rev.	6
Child Develop.	3
Circulation	8
Comput. J.	4
Crop Sci.	4
Diabetes	4
Ecology	5
Electroencephalogr. Clin. Neuro.	9
Eur. J. Biochem.	5
Evolution	3
Exp. Cell Res.	3
Gastroenterology	6
Genetics	7
Gut	4
Ibis	3
IBM J. Res. Develop.	4
IEEE Trans. Automat. Contr.	4
IEEE Trans. Inform. Theory	3
Ind. Eng. Chem.	8
Ind. Eng. Chem. Anal. Ed.	3
Int. J. Appl. Radiat. Isotop.	3
J. Abnormal Psychol.	6
J. Abnormal Soc. Psychol.	6
J. Acoust. Soc. Amer.	4
J. Amer. Chem. Soc.	31
JAMA—J. Am. Med. Assn.	7
J. Amer. Oil Chem. Soc.	7
J. Amer. Statist. Assn.	3
J. Anim. Ecol.	3
J. Appl. Behav. Anal.	7
J. Appl. Phys.	9
J. Biol. Chem.	28
J. Biophys. Biochem. Cytol.	4
J. Cell Biol.	10
J. Cell. Physiol.	3
J. Chem. Phys.	35
J. Chem. Soc.	10
J. Clin. Endocrinol. Metab.	14
J. Clin. Invest.	12
J. Clin. Pathol.	5
J. Consult. Clin. Psychol.	6
J. Dairy Sci.	7
J. Electrochem. Soc.	9
J. Exp. Anal. Behav.	5
J. Exp. Bot.	5
J. Exp. Med.	10
J. Exp. Zool.	5
J. Fish. Res. Board Can.	6
J. Fluid Mech.	7
J. Food Sci.	3
J. Geophys. Res.	13
J. Histochem. Cytochem.	5
J. Lab. Clin. Med.	8
J. Mater. Sci.	4
J. Mol. Biol.	7
J. Nat. Cancer Inst.	6
J. Nutr.	3
J. Opt. Soc. Amer.	11
J. Pediat.	4
J. Personal. Soc. Psychol.	13
J. Petrol.	4
J. Pharmacol. Exp. Ther.	3
J. Sci. Food Agr.	5
J. Sci. Instrum.	3
J. Vac. Sci. Technol.	5
J. Verb. Learn. Verb. Behav.	4
Lancet	35
Limnol. Oceanogr.	8
Medicine	5
Nature	14
N. Engl. J. Med.	28
New Phytol.	3
Nucl. Instrum. Method.	5
Nucl. Phys.	8
Pediatrics	10
Percept. Psychophys.	3
Pharmacol. Rev.	4
Phys. Rev.	23
Phys. Rev. A—Gen. Phys.	3
Phys. Rev. Lett.	4
Physiol. Plant.	5
Phytochemistry	4
Phytopathology	4
Planet. Space Sci.	3
Plant Physiol.	29
Planta	11
Proc. IEEE	21
Proc. IRE	8
Proc. Nat. Acad. Sci. US	31
Proc. Soc. Exp. Biol. Med.	6
Psychol. Bull.	23
Psychol. Monogr.	3
Psychol. Rep.	5
Psychol. Rev.	31
Psychometrika	6
Quart. Rev. Biol.	3
Quart. Rev. Chem. Soc.	3
Radiat. Res.	3
RCA Rev.	6
Rev. Mod. Phys.	12
Rev. Sci. Instr.	9
Science	30
Soil Sci.	3
Solid State Electron.	5
Trans. ASME	5
Trans. Metall. Soc. AIME	12
Transplant. Rev.	3

tant influence on their work. This fact is often revealed in editing when we add the citation frequencies to many of the author's own references. Quite often, we do this mischievously since we can often demonstrate when an author was wrong in thinking that a certain paper was ignored or little known. On the other hand, citation data may prove dramatically that he or she is right.

In addition to the systematic review of frequency-ranked author and journal lists, there are also other subjective inputs. Any reader is free to suggest that a paper is a classic in its field. I am not loathe to question such an assertion but am more than happy to confirm it. And there are many random inputs that remind us that a particular paper is a classic.

Table 4: Chronological distribution of publication dates of the 100 most-cited articles. A=publication date. B=number of papers.

A	B
1920s	1
1930s	5
1940s	8
1950s	28
1960s	41
1970s	17
	100

As of 1984, more than 500 different journals and 129 books have been represented in *Citation Classics*. Consider that there have been at least 20,000,000 papers published, and at least 10,000,000 of them since 1950. Therefore, there are at least 10,000 candidate publications if we limit our selections to one for each 1,000 published. If we continue to publish about 300 per year, it will take 30 years to cover another 10,000.

Since I would like to benefit from reading at least another 5,000 over the next decade, we will have to do something to accelerate the process. An expansion of the *Citation Classics* feature in *CC/LS* and *CC/PC&ES* is one obvious solution. Another is to create a new supplementary publication called the "Journal of *Citation Classics*." Yet another is to publish commentaries in other journals. There is always the danger of too much of a good thing, but considering the size of the scientific enterprise, we have only scratched the surface. Derek J. de Solla Price used to talk about the "Journal of Really Important Papers." I think he might have accepted the "Journal of *Citation Classics*" as a compromise for the science historian, if not the working scientist.

We are also planning to publish collections of *Citation Classics* in separate volumes as interesting models of discovery. While collections of highly cited papers may not provide a uniform selection of the "best" in any field you care to mention, they do provide an amazing sample of high-impact research. Although certain journals do have their usual expected list of methods classics, most do not, as can be demonstrated by an article-by-article examination of the classics for many leading journals.

It has been some time since we have published a list of the all-time *Citation Classics*.[7,8] Most of the papers in Table 1 have been mentioned before, in one essay or another. No need to comment further on the ubiquitous anomaly of the Lowry method.[9] However, since we last looked at the top 100 back in 1974, a number of newcomers have turned up. Of the original 1974 list, only 44 of the same papers appear in Table 1. Two asterisks (**) indicate that the paper did not appear in the earlier list. This is a rather large shift. It remains to be seen whether the remaining group of 56 classics turn up in our future lists. Old classics rarely die. They don't even fade away. What makes them so different from papers that are "obliterated" is part of the exciting dynamics of the human process we call research.

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