Current Comments

Citation Classics—Four Years of the Human Side of Science

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Most readers of *Current Contents*® (*CC*®) are by now familiar with the *Citation Classics* feature which began in 1977. It seems to me that after four years of this weekly feature an evaluation is now in order.

In reviewing *Citation Classics*, one is immediately struck by the fact that our goals have changed somewhat in the past four years. Originally, we planned to draw our classics from a "group of 500 papers most-cited during the years 1961-1975."[1] By 1979, however, we realized the consequences of this narrow approach to selecting papers. Most of the 500 most-cited papers came from the life sciences. There are many reasons for this. Consequently, in 1979, in order to make our coverage more comprehensive and representative of all the fields of science, we began to publish six different classics each week—one for each edition of *CC*,[2] except *Arts & Humanities*. And in early 1981, to eliminate our backlog we began publishing two classics in *CC/Life Sciences* per week.

While citation frequency is a prime indication of a paper's impact, we have not rigidly adhered to any particular level of citation. A paper in one of the basic engineering sciences may be a classic even if it has been cited only 30 or 40 times. This would still be orders of magnitude greater than the number of citations received by millions of average papers even in the life sciences. And in the social sciences, as in engineering, books often are as important as journal articles so we must apply separate criteria for them.

Apart from expanding the definition of a *Citation Classic* so that it comes closer to what scientists perceive as a classic, our basic goal in publishing *Citation Classics* has remained the same: to present the human side of science while paying tribute to diverse advances in science and scholarship. These commentaries were designed to allow scientists to talk about their major works from a personal standpoint, revealing what prompted the research, the contributions of coauthors, and obstacles that were encountered in both research and publication—in short, those details that are rarely revealed in formal scientific publication. The more than 750 classics published so far have exceeded my expectations.

I think it is unfortunate that scientific journals do not have the flexibility or the sense to provide some of this background. But in the context of a scientific journal, it may not be particularly relevant to learn, for example, that Martin Seligman's paper on the laws of learning resulted from an illness he contracted after eating béarnaise sauce.[3] In this particular instance, although the illness was not related to the eating experience, it so conditioned Seligman that he

still (15 years later) cannot eat béarnaise sauce. The paper grew out of his conjectures on why this is so.

Once we have determined through various citation analyses that a paper is a milestone paper in its field, how do we get the essays, or vignettes, written? First, we contact the author and ask him or her to prepare a commentary. The author also receives an author's guide which explains the feature and the kind of information we'd like included in the commentary. The author also receives samples of published *Citation Classics*. We encourage the author to stress the personal factors involved in getting the original paper published and we ask for information about coauthors, and how and where the work took place. One of the most important questions is why he or she thinks the publication has been cited so often. In order to make the essay topical for readers interested in following up on the subject, we ask the author to cite a more recent review article or publication. We also ask each author to mention any awards or honors that resulted from the research. This is further confirmation that it is indeed a classic. I take particular pleasure in noting that the authors of several classics went on to be recipients of the National Academy of Sciences award for scientific reviewing![4,5]

Since we began *Citation Classics* in 1977, we've extended invitations to over 2,000 authors. It is somewhat disappointing to me that only about one third have accepted. Of course if we had a better response we'd have written fewer letters, but eventually we would have covered all of them. Another 100 authors have promised to send manuscripts, but have yet to do so. We telephone most to reinvite them. Nearly half of those asked, however, have simply never acknowledged our letters. We can't even be sure they were delivered. This is to be expected since many have moved.

I had been concerned about the possibility that an inordinate percentage of refusals and nonresponses involved foreign authors. What if some of these authors are unable or unwilling to prepare a commentary in English? But in fact about 30 percent of nonrespondents are from outside the US, closely comparable to what one would expect from the number of classics published. It also turns out that the refusal rate of about 50 percent for authors in English-speaking countries is almost identical for the other countries. This would dispel the notion of an English-language bias.

The average age of the classics covered today is 19 years, and the vast majority of classics (454) were published in the 1960s. One hundred sixty-one were published in the 1950s, 73 in the 1970s, 35 in the 1940s, and five in the 1930s. Of course, some authors have died since writing their classic articles, but we do accept surrogates if a coauthor is not available. About 100 authors responded but refused our invitation.

I am delighted to report that 14 Nobel prizewinners, not to mention dozens of other prizewinners and academy members, have taken the time to write about their *Citation Classics*. These positive responses make the varied reasons for refusal hard to comprehend. Some authors claimed a lack of time, others a lack of interest in their original papers, and still others expressed a feeling that it just wasn't worth the effort, especially if they have left the field. I think it is unfortunate because these authors deny their colleagues and society a perspective on their work that they alone can provide. In the future, we intend to ask one of their colleagues or students if they will prepare essays. These commentaries may become a part of our

forthcoming *Encyclopedic Atlas of Science*. And we hope to publish collections of these essays for use by graduate students and others interested in the way science actually works.

From the time the first *Citation Classics* was published on January 3, 1977, until the last classic of 1980 on December 29, 1980, we covered 728 classics in *CC*. By the end of 1981 this figure will exceed 1,000! Figure 1 provides a breakdown for the 24 countries represented at the time the authors published their classic papers. Most authors came from English-speaking countries. The US accounted for 502 papers, over two thirds; the United Kingdom, 93; Canada, 29; and Australia, 19. All but three of the original publications were in English. Of the remaining three, two were published in French, and one in German. One author claimed that when he first published his results in French journals the work received little attention.[6] While this was not necessarily true for papers published in the 1950s, it is clear that publication in any foreign language today can delay recognition of significant work.[7] Not all scholars accept this explanation alone, however. Derek J. de Solla Price, Yale University, for example, suggests that the preponderance of papers from English-speaking countries may be due in part to what he feels is an English-speaking bias in our citation index.[8] I would argue that our bias is towards the high impact journals, regardless of their language. And it is quite possible that a few Russian authors are overlooked because citations to their papers may be fragmented in vernacular and translation journals.

Figure 1: Countries which produced original *Citation Classics* articles, with the number of papers from each.

Country		Number of Papers
US		502
United Kingdom		93
England	84	
Scotland	8	
Wales	1	
Canada		29
Australia		19
Sweden		11
Federal Republic of Germany (FRG)		6
France		5
Denmark		3
Israel		3
Japan		2
South Africa		2
Switzerland		2
Argentina		1
Belgium		1
Finland		1
German Democratic Republic (GDR)		1
India		1
Mexico		1
The Netherlands		1
New Zealand		1
Spain		1
USSR		1
Not available		41

Nearly 250 different institutions are represented in Figure 2 which lists addresses for the original publications. However, since many authors have moved, they now work at over 315 different institutions which are listed in Figure 3. If overlaps are eliminated, there are over 425 institutions. To save space we have not repeated the names of institutions named in Figure 2. The fact that so many new institutions show up in Figure 3 illustrates the growth of research worldwide and the migration of classic authors to other institutions. While most worked at academic institutions, industry and government are well-represented. These figures are based on the use of the addresses for first authors only. I doubt that including second authors would change much in this case.

As could be expected from the examples set by our other citation studies, a few institutions dominate the lists. The combined campuses of the University of California, for example, top both lists. Forty classics were written at California, but 55 authors are now currently at work there. The migration to the west-

Figure 2: The institutional affiliations of *Citation Classics* authors, at the time they wrote their classic papers, with the number of authors from each.

- University of California 40
  - Berkeley 17
  - Davis 3
  - Irvine 1
  - Livermore 1
  - Los Angeles 7
  - Riverside 2
  - San Diego 3
  - San Francisco 5
  - Santa Barbara 1
- Natl. Inst. Health 25
  - Natl. Cancer Inst. 10
  - Natl. Heart, Lung and Blood Inst. 6
  - Natl. Inst. Allergy and Infectious Disease 3
  - Natl. Inst. Arthritis, Metabolism and Digestive Disorders 2
  - Natl. Inst. Child Health and Human Development 1
  - Natl. Inst. Dental Res. 3
- University of Wisconsin 24
- Harvard University 22
- Bell Labs., Murray Hill and Holmdel, NJ 18
- University of London 18
  - Birbeck Coll. 1
  - Imperial Coll. Science and Technology 3
  - Inst. Cancer Res. 2
  - Inst. Child Health 1
  - Inst. Psychiatry 1
  - Lister Inst. Preventive Med. 1
  - Middlesex Hosp. Med. Sch. 4
  - Royal Holloway Coll. 1
  - Royal Postgraduate Med. Sch. 3
  - University Coll. 1
- Johns Hopkins Univ. and Hosp. 14
- Stanford University 13
- California Inst. Technology 11
- Columbia University 11
- University of Cambridge 11
- University of Chicago 11
- University of Illinois 11
- University of Pennsylvania 10
- University of Washington, Seattle, WA 10
- Cornell University 9
- University of Texas 9
- General Electric Co., Schenectady, NY 7
- Massachusetts Inst. Technology 7
- University of Minnesota 7
- Yale University 7
- Carnegie-Mellon University 6
- Oxford University 6
- US Department of Agriculture 6
  - Agriculture Res. Ctr., Beltsville, MD 3
  - Cereal Science and Foods Lab., Peoria, IL 1
  - Agricultural Marketing Serv., Beltsville, MD 1
  - Regional Poultry Res. Lab., East Lansing, MI 1
- University of Michigan 6
- University of Rochester 6
- Brookhaven Natl. Labs., Upton, NY 5
- Duke University 5
- McGill University, Montreal, Canada 5
- Natl. Bureau of Standards, Washington, DC 5
- Natl. Res. Council of Canada 5
- State University of New York 5
- University of Colorado 5
- Washington University, St. Louis, MO 5
- Commonwealth Scientific and Industrial Res. Organization (CSIRO), Australia 4
- New York University 4
- Northwestern University 4
- Pennsylvania State University 4
- University of Edinburgh 4
- University of Lund, Sweden 4
- University of Melbourne 4
- University of Oregon 4
- University of Toronto 4
- IBM Corp., Yorktown Heights, NY 3
- Indiana University 3
- Iowa State University 3
- Mayo Clinic and Foundation, Rochester, MN 3
- Michigan State University 3
- NASA, Greenbelt, MD 3
- Purdue University 3
- RCA Labs., New York, NY 3
- Rockefeller University 3
- US Naval Res. Lab., Washington, DC 3
- University of Adelaide 3
- University of Pittsburgh 3
- University of Reading, UK 3
- Weizmann Inst. Science, Rehovot, Israel 3
- Albert Einstein Coll. Med., New York, NY 2
- Avco-Everett Res. Lab., Everett, MA 2
- Baylor University, Waco, TX 2
- Brown University, Providence, RI 2
- Bucknell University, Lewisburg, PA 2
- Canadian Department of Agriculture 2
- Case Western Reserve University 2
- Colonial Sugar Refining Co., Indooroopilly, Australia 2
- Dow Chemical Co., Midland, MI 2
- E. I. Du Pont de Nemours and Co., Wilmington, DE 2
- Haskins Labs., New Haven, CT 2
- Humble Oil Co., Houston, TX 2
- Inst. Pasteur, Paris, France 2
- Massachusetts General Hosp., Boston, MA 2
- Medical Res. Council, UK 2
- Mount Sinai Sch. Med., New York, NY 2
- Natl. Inst. Med. Res., Mill Hill, UK 2
- Natl. Physical Lab., Middlesex, UK 2
- Ohio State University 2
- Oregon State University 2
- Peter Bent Brigham Hosp., Boston, MA 2
- Princeton University 2
- Public Health Res. Inst. of the City of New York 2
- Rothamsted Experimental Station, Harpenden, UK 2

State University of Iowa 2
UK Atomic Res. Estab., Harwell, UK 2
US Air Force 2
US Army 2
US Public Health Serv. 2
US Steel Corp., Pittsburgh, PA 2
University of Birmingham 2
University of Bristol 2
University of Georgia 2
University of Kansas 2
University of Miami 2
University of Montreal 2
University of Stockholm 2
Veterans Admin. Hosp., Bronx, NY 2
Virginia Polytechnic Inst. and State University 2
Walter and Eliza Hall Inst. Med. Res., Melbourne, Australia 2
Wellcome Res. Lab., Kent, UK 2
Woods Hole Oceanographic Inst., Woods Hole, MA 2
Aarhus University, Risskov, Denmark 1
Abbott Labs., Chicago, IL 1
Academy of Natural Sciences, Philadelphia, PA 1
Academy of Sciences of the GDR 1
Allied Chemical Corp., Morristown, NJ 1
American Cyanamid Co., Stanford, CT 1
Argonne Natl. Lab., Argonne, IL 1
Australian Department of Science and Industrial Res. 1
Australian Natl. Observatory 1
Australian Natl. University 1
Bonneville Power Admin., Portland, OR 1
Bowling Green State University, OH 1
British Museum, London, UK 1
British Postgraduate Med. Sch., London, UK 1
Canadian Department of Fisheries 1
Cardiff Royal Infirmary, UK 1
Chester Beatty Res. Inst., London, UK 1
Children's Asthma Res. Inst. and Hosp., Denver, CO 1
Children's Hosp., Boston, MA 1
Clinical Res. Ctr., Harrow, UK 1
College of Veterinary Med., Finland 1
Crookes Labs., Ltd., London, UK 1
Defense Res. Board, Canada 1
Defense Res. Estab., Canada 1
Dennison University, Granville, OH 1
Distiller's Co., Epsom, UK 1
Eastman Kodak Co., Rochester, NY 1
Essex University, Colchester, UK 1
Fairchild Camera and Instrument Corp., Palo Alto, CA 1
Fels Res. Inst., Yellow Springs, OH 1
Free Hosp. for Women, Brookline, MA 1
Geophysics Corp. of America, Bedford, MA 1
Glynn Res. Labs., Badmin, UK 1
Grasslands Res. Inst., Hurley, UK 1
Heyden Chemical Corp., Garfield, NJ 1
Hoffmann-La Roche, Nutley, NJ 1
Hosp. Infantil de Mexico, Mexico City, Mexico 1
Houghton Poultry Res. Station, Houghton, UK 1
Illinois Inst. Technology, Chicago, IL 1
Illinois Wesleyan University, Bloomington, IL 1
Imperial Cancer Res. Fund, London, UK 1
Imperial Chemical Indust., Welwyn Garden City, UK 1
Indian State Institution, New Delhi, India 1
Inst. Advanced Study, Princeton, NJ 1
Inst. Cancer Res., Philadelphia, PA 1
Inst. Fisheries Investigation, Spain 1
Inst. Psychiatric Res., Indianapolis, IN 1
Inst. Res. Cancer, Villejuif, France 1
Inst. Investigaciones Bioquímicas, Buenos Aires, Argentina 1
Jackson Lab., Bar Harbor, ME 1
Jewish Hosp., St. Louis, MO 1
Johannes Gutenberg University, Mainz 1
Kansas State University, Manhattan, KS 1
Karolinska Inst., Stockholm, Sweden 1
King Gustav V. Res. Inst., Stockholm, Sweden 1
École Normale Supérieure, Paris, France 1
Lund Inst. Technology, Sweden 1
M.D. Anderson Hosp. and Tumor Institution, Houston, TX 1
Martin Marietta Corp., Baltimore, MD 1
Massachusetts Mental Health Ctr., Boston, MA 1
Maudsley Hosp., London, UK 1
May Inst. Med. Res., Cincinnati, OH 1
Mead Johnson & Co., Evansville, IN 1
Medical Coll. Georgia, Augusta, GA 1
Methodist Hosp., Indianapolis, IN 1
Minnesota Mining & Manufacturing Co., St. Paul, MN 1
Mixing Equipment Co., Rochester, NY 1
Mobile Oil Co., Princeton, NJ 1
Natl. Inst. Mental Health, Rockville, MD 1
Natl. Vegetable Res. Station, Wellesbourne, UK 1
Natl. Women's Hosp., Auckland, New Zealand 1
New York Blood Center, NY 1
Nobel Medical Inst., Stockholm, Sweden 1
North Carolina State University 1
Oak Ridge Natl. Lab., TN 1
Ohio Agricultural Experimental Station, Columbus, OH 1
Ontario Cancer Inst. 1
Ontario Res. Foundation 1
Pneumoconiosis Res. Unit, Johannesburg, South Africa 1
Polytechnic Inst. New York, Farmingdale, NY 1
Portsmouth & Isle of Wight Area Pathology Serv., Portsmouth, UK 1
Quartermaster Res. and Engineering Ctr., Natick, MA 1
Research Board of Canada 1
Rijksuniversiteit Leiden, The Netherlands 1
Rockwell Park Memorial Inst., Buffalo, NY 1
Rowett Inst., Bucksburn, UK 1
Royal Coll. Science, London, UK 1
Royal Coll. Surgeons of England, London, UK 1

Royal Danish Sch. Pharmacy, Copenhagen, Denmark	1
Royal Radar Estab., Worcester, UK	1
Royal Signals & Radar Estab., Malvern, UK	1
Rutgers University, New Brunswick, NJ	1
St. Mark's Hosp., London, UK	1
Shell Development Co., Emeryville, CA	1
Sinclair Res. Labs., Harvey, IL	1
Sloan-Kettering Inst. Cancer Res., Rye, NY	1
Sorbonne, Paris, France	1
Squibb Inst. Med. Res., NJ	1
Standard Oil Co., Whiting, NJ	1
Swiss Federal Inst. Technology, Zurich, Switzerland	1
Technische Hochschule Stuttgart, FRG	1
Tohoku Pharmaceutical Sch., Sendai, Japan	1
Torry Res. Station, Aberdeen, UK	1
Tufts University	1
Tulane University of Louisiana	1
US Department of Commerce	1
US Department of Health, Education, and Welfare	1
US Department of Interior	1
US Geological Survey	1
University College, Swansea, UK	1
University College of Wales, UK	1
University of Aberdeen	1
University of Alaska	1
University of Arkansas	1
University of Bern, Switzerland	1
University of Bradford, UK	1
University of British Columbia	1
University of Cincinnati	1
University of Connecticut	1
University of Copenhagen	1
University of Durham	1
University of Düsseldorf	1
University of Florida	1
University of Freiburg	1
University of Geneva	1
University of Glasgow	1
University of Hawaii	1
University of Leeds	1
University of Liverpool	1
University of Louvain, Belgium	1
University of Manchester	1
University of Manitoba	1
University of Marburg	1
University of Maryland	1
University of Munich	1
University of Natal, South Africa	1
University of Nebraska	1
University of Newcastle-upon-Tyne	1
University of North Carolina	1
University of Ottawa	1
University of Sydney	1
University of Tennessee	1
University of Tokyo	1
University of Uppsala	1
University of Utah	1
University of Vermont	1
University of Waterloo, Canada	1
University of Western Ontario	1
Vanderbilt University	1
Varian Associates, Palo Alto, CA	1
Veterans Admin. Hosp., Durham, NC	1
Veterans Admin. Hosp., Little Rock, AR	1
Veterans Admin. Hosp., White River Junction, VT	1
Wake Forest University, Winston-Salem, NC	1
Westinghouse Electric Corp., Pittsburgh, PA	1
Westminster Hosp., London, UK	1
Wheeler Labs., Great Neck, NY	1
Wistar Inst., Philadelphia, PA	1
World Data Ctr., Moscow, USSR	1

Figure 3: *Citation Classics* authors' current institutional affiliations which were not listed in Figure 2. The number of authors from each is also shown.

Brigham Young University, Provo, UT	3
Tel Aviv University, Israel	3
Temple University, Philadelphia, PA	3
University of Arizona	3
University of Delaware	3
Brandeis University, Waltham, MA	2
CERN (European Organization for Nuclear Res.) Geneva, Switzerland	2
City University of New York	2
Colorado State University	2
Exxon Corp., Houston, TX	2
Hahnemann Med. Coll. and Hosp., Philadelphia, PA	2
University of Alberta, Edmonton, Canada	2
University of Guelph, Ontario, Canada	2
University of Oklahoma	2
University of Paris	2
University of Southampton	2
York University, Downsview, Ontario, Canada	2
Addenbrooke's Hosp., Cambridge, England	1
Aeronautical Res. Lab., Melbourne, Australia	1
All India Inst. Med. Sci., New Delhi, India	1
American University, Washington, DC	1
ARCO, Harvey, IL	1
Arizona State University	1
Bispeberg Hosp., Copenhagen, Denmark	1
Bolt Beranek & Newman, Inc., Cambridge, MA	1
Boston University	1
Bruce Lyon Memorial Res. Lab., Oakland, CA	1
Brunel University, Uxbridge, UK	1
Brussels University, Belgium	1
CNRS, Strasbourg, France	1
California Department of Health	1
Canadian Wildlife Serv.	1
Cancer Control Agency of British Columbia, Vancouver, Canada	1
Cardiovascular and Chest Surgical Associates, Boise, ID	1
Carlsberg Foundation, Copenhagen, Denmark	1
Ctr. Studies of the Person, La Jolla, CA	1
Chalmers Inst. Technology, Göteborg, Sweden	1

Children's Hosp. Med. Ctr., Cincinnati, OH	1
City of Hope Natl. Med. Ctr., Duarte, CA	1
Claremont Graduate Sch., CA	1
Clinical Res. Inst., Montreal, Canada	1
College of William & Mary	1
Communication Res. Ctr., Ottawa, Canada	1
Decision Res., Eugene, OR	1
Denver General Hosp.	1
Dickinson College, Carlisle, PA	1
École National Supérieure des Mines, Paris, France	1
Ecology and Environment, Inc., Decatur, GA	1
Educational Testing Serv., Princeton, NJ	1
Florida Medical Entomology Lab., Vera Beach, FL	1
Freeman Hosp., Newcastle-upon-Tyne, UK	1
Funk Seeds Internatl., Bloomington, IL	1
Georgetown University, Washington, DC	1
Hampshire District Pathology Serv., Portsmouth, UK	1
Harris Corp., Melbourne, FL	1
Hazeltine Corp., Greenlawn, NY	1
Hôp. de l'Enfant Jesus, Quebec, Canada	1*
Hughes Aircraft Co., Fullerton, CA	1
Hungarian Academy of Sciences, Budapest	1
Ibaraki University, Meto, Japan	1
Indian Inst. Science, Bangalore, India	1
Indiana Sch. Med.	1
Inst. Animal Physiology, Cambridge, UK	1
Inst. Biochemistry and Technology, Munster, FRG	1
Inst. Nacional de Ciencias y Technologia, Mexico	1
Intel Corp., Santa Clara, CA	1
International Lab. Res. Animal Diseases, Nairobi, Kenya	1
Israel Inst. Technology, Haifa	1
Justus-Liebig University, Geissen, FRG	1
LaTrobe University, Bundoora, Australia	1
Lehigh University, Bethlehem, PA	1
Letterman Army Inst. Res., San Francisco, CA	1
Lewisham Hospital, London, UK	1
Llandough Hosp., Penarth, UK	1
Loma Linda University Med. Ctr., CA	1
Long Island University, Greenvale, NY	1
Louisiana State University	1
Loyola University, Maywood, IL	1
McMaster University, Hamilton, Canada	1
Meat Res. Inst., Langford, UK	1
Michigan Technological University, Houghton, MI	1
Midwest Med. Lab., St. Louis, MO	1
Mill Hill Labs., London, UK	1
Mississippi State University	1
Monash University, Clayton, Australia	1
Montifiore Hosp. and Med. Ctr., New York, NY	1
Mt. Holyoke College, South Hadley, MA	1
Natl. Jewish Hosp. and Res. Ctr., Denver, CO	1
New York Med. Coll., NY	1
Oak Ridge Associated Universities, TN	1
Optical Sciences Co., Placentia, CA	1
Pace University, New York, NY	1
Peter MacCullum Hosp., Melbourne, Australia	1
Pittman-Moore, Glenorie, Australia	1
Polish Academy of Sciences, Warsaw, Poland	1
Portland State University	1
Queen Elizabeth Med. Ctr., Birmingham, UK	1
Queen's University, Kingston, Canada	1
Queen's University of Belfast, UK	1
Research & Laser Technology, Inc., Rockport, MA	1
Rheinische-Westfälische Technische Hochschule, Aachen, FRG	1
Rice University, Houston, TX	1
Royal Infirmary, Glasgow, UK	1
Royal Liverpool Hosp., Liverpool, UK	1
Rutgers Med. Sch., Piscataway, NJ	1
San Diego State University	1
Soroka Med. Ctr., Beer-Sheba, Israel	1
Southern Illinois University	1
Strangeways Res. Lab., Cambridge, UK	1
Swedish Department of Occupational Health	1
Syracuse University	1
Tokyo Inst. Technology, Japan	1
Tropical Products Institution, London, UK	1
US Food and Drug Admin.	1
USSR Academy of Science, Moscow	1
Uniformed Services University of the Health Services, Bethesda, MD	1
Unilever Res. Lab., Sharnbrook, UK	1
University of Alabama	1
University of Amsterdam	1
University of Auckland	1
University of Barcelona	1
University of Basel	1
University of Exeter	1
University of Göteborg, Sweden	1
University of Haifa, Israel	1
University of Iowa	1
University of Kentucky	1
University of Laval, Canada	1
University of Pierre and Marie Curie, Paris	1
University of Rhode Island	1
University of Saarland, FRG	1
University of Southern Alabama	1
University of Southern California	1
University of Sussex	1
University of Vienna	1
University of Virginia	1
University of Würzburg, FRG	1
Upjohn Co., Kalamazoo, MI	1
Varian/Extrio, Gloucester, MA	1
Veterans Admin. Ctr., Louisville, KY	1
Veterans Admin. Hosp., Miami, FL	1
Veterans Admin. Hosp., San Diego, CA	1
Washington State University, Pullman, WA	1
Western Michigan University	1
West Park Hosp., Epsom, UK	1
Wittenberg University, Springfield, OH	1
YMCA Tribal Development Project, Tamil Nadu, India	1
Retired	34

*One or more of these authors represents a second affiliation.

ern US is significant. Also high on both lists are National Institutes of Health, 25 classics; University of Wisconsin, 24; Harvard, 22; Bell Labs., 18; University of London, 18; Johns Hopkins, 14; and Stanford, 13. Also prominent are Cornell, Columbia, University of Cambridge, University of Chicago, University of Pennsylvania, University of Washington, University of Texas, and State University of New York.

If we eliminate those institutions which account for only one paper, only 98 account for 523 classics. Similarly, only 105 institutions are involved in current affiliations. Seventy-three of these institutions appear on both lists. In Figure 4 there is a table showing the number of institutions which accounted for one or more classic papers.

Figure 4: The number of institutions which accounted for one or more classic papers.

Number of Papers	Number of Institutions
40	1
25	1
24	1
22	1
18	2
14	1
13	1
11	5
10	2
9	2
7	4
6	5
5	8
4	9
3	14
2	42
1	159

We also studied the number of authors per paper. It is significant that there are so many single-authored papers—302. Nevertheless, multi-authored papers dominate. Of these, however, 245 had only two authors. Papers in clinical medicine had an average of three authors, more authors than the other disciplines. We also know that high-energy physics papers have many authors. Figure 5 shows the number of papers for each group. The average number of authors per paper in the classics is 2.06. This is significantly lower (20 percent) than the 2.56 average for papers covered by the *Science Citation Index®* (*SCI®*) in 1980.

Which types of papers become *Citation Classics*? We know that superstar methodology papers, especially in biochemistry, are to be expected. Nevertheless, less than one fourth of the papers involved are methodological. Almost one third were theoretical or experimental. The remaining large category was review papers—about 100. And another large group was papers or books which provided oft-cited tables and data of one kind or another or "tests." These are only crude measures, but it should dispel the notion that methodology papers dominate citation studies. But once a well-known procedure is adopted it may be cited thousands of times. The interesting question is why a small number of such classics fail to succumb to the obliteration phenomenon.

Why are articles cited? The answer may seem, at first glance, quite simple, yet no one really knows—least of all the cited authors themselves! A surprising number of authors, upon receiving our request to comment upon their *Citation Classic*, have themselves questioned why their papers were cited. An equally large number of authors assert in their commentaries that they don't really know why they've been cited. It's amazing how many were not really aware how often or by whom they were cited. Only a small number are interested enough to go back to the citing papers through the *SCI* to find out exactly why they've been cited. In correspondence with some authors, I've pointed out that only a content analysis of the citing papers can reveal the "why" of citation.

Figure 5: The number of authors per paper.

Number of Authors	Number of Papers
1	302
2	245
3	92
4	47
5	25
6	10
7	3
8	1
9	1
10	1
11	1

I also send them copies of a few ISI® papers in which we have done content analyses[9,10] and recommend they get students to help with the library work involved.

Of course, many authors maintain extensive reprint collections related to their discoveries or have an intense interest in the way their work has been applied. Hans Krebs, for example, in his *Citation Classic*,[11] quotes from an historical evaluation of his classic paper on urea formation. But most authors merely make educated guesses as to why they've been cited so often. I urge them to do these content analyses because they can lead to important review papers.

Authors frequently assert that timeliness was the main reason their papers had so much impact. Many feel that if their work had appeared earlier or later, it might not have received much notice. Others maintain that their papers were cited simply because they developed an often-used formula or procedure. Others believe that their papers were highly cited simply because they included a comprehensive review of the literature. But in my studies I have found that the influence of the *critical* review is significant—it doesn't simply serve as a convenient way to cite the earlier literature. Equally important, some of these authors correctly believe that the new or surprising or even the startling results published in their papers stimulated more work on the same topic. Sometimes the citing author makes this self-evident, but more often than not this is only implied in the work.

Most authors correctly assume that their papers were cited for positive reasons. Only a few authors feel that their work was also cited for negative reasons, although in at least one case, the paper was often cited for negative reasons.[12,13]

Understanding the "why" of citation is an area of research that interests sociologists of science. In fact, Susan Cozzens of ISI has recently summarized various theories about citations,[14] and in particular Mike Moravcsik, Oregon University, has examined the types of citations in physics in detail.[15] Their studies may lead to a better understanding of the processes of scientific discovery. In *The Force of Knowledge*, John Ziman, our salty colleague from the University of Bristol and editor of the *Philosophical Magazine* (a physics journal), points out the importance of citations to scientific knowledge:

> A typical scientific paper is full of references or citations to the experiments, calculations, observations, or theories of other people. It does not strike out on its own into the unknown, but timidly takes one little step forward from the base secured by previous research. In other words, modern research is highly collaborative, despite all the competition. Everything we do is deeply indebted to, and embedded in, the achievements of our predecessors and contemporaries in our Invisible College.[16] (p. 100-1)

In a 1971 article on citation indexes prepared by ISI for the *Encyclopedia of Library and Information Science*, we listed 15 reasons that authors cite other works. Among them were to pay homage, to identify methods or equipment,

to provide background reading, and to give credit for related work.[17]

What some authors fail to recognize is that their "simple" discoveries make it possible for others to go on to do studies that were previously impossible. In evaluating the relative impact of highly cited papers the authors themselves can take the simplistic approach and assume that a paper was cited *simply* because a certain method or theory is used. But just as often the methodology is intertwined with other complex ideas that may never have been developed had not the methodology been employed. This was certainly the case recently when we examined why the work of R.M. Campbell *et al.* was cited.[18]

Perhaps the most fascinating aspect of *Citation Classics* is the perception of the author in evaluating the importance of the work in question. There is often a sense of irritation that we were not wise enough to realize that his or her most-cited work was not his or her most important. While we never make that assumption, it is somewhat distressing that we are resented because there is not a one to one correlation between citation frequency and the author's evaluation of importance. Clearly many authors feel, and correctly so, that the classic article we have selected *is* their most important work. But the opposite reaction of Heinz Fraenkel-Conrat and his coauthors is typical of many other classic authors. "All three authors have at least ten other papers to their credit which they would list above this one in importance. And what this paper is quoted for is not its intrinsic point (which had some importance) but for the fact that it contains a paragraph describing the method of washing and suspending commercial bentonite clay."[19] What Fraenkel-Conrat and others might have added is that some of their other articles were not only important papers but also qualify as *Citation Classics.*

Harriet Zuckerman, Columbia University, in her book *Scientific Elite*[20] discusses the phenomenon of the scientist who doesn't feel his highly acclaimed work is his most important. A significant number of Nobel prizewinners have these feelings. She offers some possible explanations. One, she says, is the fact that often the highly acclaimed work was the result of chance or serendipity. To some scientists, this seems less important, or valid, than something that was well thought-out or planned.[20]

Drawing on the work of Robert Merton, Columbia University, on the behavior of scientists, which demonstrated a common scientific drive for "recognized originality,"[21] Zuckerman further points out that since often an acclaimed work represents an accidental discovery, for many scientists this is not considered particularly original. Thus such work is not as meaningful as a work that would "deepen scientists' understanding of large problems."[20] (p. 211) Many Nobelists seem to feel that if it hadn't happened to them, it would have happened to someone else. We have here the idea that many discoveries are "inevitable." One wonders how much this kind of thinking pervades the halls of Congress these days.

Finally, says Zuckerman, there may often be a disparity between the personal significance of a work to its author, and the scientific significance of the same work,[22] that is, the acceptance of his or her peers. It's one thing to correlate an author's personal perception of importance to that of his or her peers and another to match this with actual impact as measured by citation frequency.

Still another explanation is offered by Lewis Goldberg, University of Oregon. In writing about his classic on the human judgment process, he notes that people frequently employ a technique he calls "availability" in decision mak-

ing. "When people have to estimate the frequency of an event," he writes, "they typically rely on the ease with which instances spring to mind. Use of such a tactic is not unreasonable, but under some circumstances it can lead us astray (e.g. the frequency of more striking or memorable events gets overestimated). So it is with me: had someone asked me to estimate which of my publications was the most frequently cited, I'd certainly have selected another!"[23]

Taking a slightly different tack, Price hypothesizes that a failure of communication may actually be a major part of the problem. Many authors, he feels, are simply unable to evaluate their effectiveness at communication. An author, says Price, may well have discovered "the discovery to end all discoveries," but if he or she doesn't communicate that to others, it has little value. In other words, an author may be aware of the scientific quality of his or her work, but have no idea of the quality of communication. And, Price continues, citation frequency must be a product of the inherent quality of a work and the effectiveness of its communication.[8] He concludes that whether we like it or not, the citation record is the most accurate index of the world scientific community's opinion of a scientist we have available.[24]

The reader is, of course, the ultimate judge of whether the space and energy devoted to *Citation Classics* is worth the effort. I continue to read each and every classic before it is published. The quality has improved enormously over the years and in many instances we have been able to call attention to important work that has otherwise not been acknowledged. That many of the papers did elicit awards confirms our choice, but I take special satisfaction in serving as a public relations catalyst for many scientists who receive inadequate recognition for their work. Indeed, a large number of individuals turn up here who do not show up on our lists of most-cited authors. This illustrates that not only the superstars make important contributions to progress. I also hope it emphasizes the need for scientists and administrators to concentrate on publishing fewer papers of higher quality and hopefully higher impact.

Perhaps one of the most important contributions our *Citation Classics* series has made is that we now have extensive examples of significant discoveries that were entirely unplanned, and in fact, often accidental. This serendipitous theme is quite prevalent. As L. Révész of the Karolinska Institute observed: "Clearly, this is another example of how futile it is to try to foresee the path of fundamental research, to say nothing of governing it."[25] *Citation Classics* can serve as an excellent model of the actual discovery process. It is for this reason that we hope to publish them in a collection for use by graduate students and others.

In closing, may I urge every *CC* reader to inform us of any paper or book which may qualify as a *Citation Classic*. Each suggestion will be carefully evaluated and, if we agree, the authors will receive an invitation at the earliest opportunity. We are not referring here to unrecognized but important research. That is an entirely separate area of research which we are studying intensively. We will discuss these "sleepers" in the future. And when we complete the compilation of the *SCI* for 1955-1964, we will be better able to identify certain classics which very quickly after publication became a part of the common wisdom of science.

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